DOCUMENT RESUME

ED 317 840 CE 054 710

AUTHOR	Wells, Judith A.; And Others
TITLE	Greenhouse Operation and Management. Instructor Guide and Student Reference. Missouri Agricultural Education. Volume 21, Number 3.
INSTITUTION	Missouri Univ., Columbia. Instructional Materials Lab.
SPONS AGENCY	Missouri State Dept. of Elementary and Secondary Education, Jefferson City. Div. of Vocational and Adult Education.
PUB DATE	Jan 90
NOTE	397p.
AVAILABLE FROM	Instructional Materials Laboratory, University of Missouri, 2316 Industrial Drive, Columbia, MO 65202 (instructor guide, order no. 10-2010-I: $22.60; student reference, 10-2010-S: $8.45).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052) -- Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Administration; Business Skills; Climate Control; Competency Based Education; Curriculum Guides; Educational Objectives; Energy Conservation; Fertilizers; *Greenhouses; Insecticides; Marketing; *Nursery Workers (Horticulture); Occupational Information; Occupational Safety and Health; *Ornamental Horticulture; *Plant Growth; Plant Identification; *Plant Pathology; Plant Propagation; Secondary Education; Vocational Education

ABSTRACT

These student and instructor materials for a one-semester course intended for high school juniors and seniors teach the following 24 lessons: (1) the scope and development of greenhouse production; (2) the economic importance of greenhouse crops; (3) careers in greenhouse operation and management; (4) greenhouse parts, structures, and coverings; (5) greenhouse environmental control; (6) interior layout; (7) energy conservation; (8) plant parts, structures, and functions; (9) plant processes; (10) environmental effects on plant growth; (11) growth regulation; (12) floriculture plant identification; (13) sexual plant propagation; (14) asexual plant propagation; (15) growing media; (16) containers; (17) watering; (18) fertilizers and plant nutrition; (19) common greenhouse pests and diseases; (20) techniques and equipment used to apply pesticides; (21) pesticide safety; (22) marketing floricultural crops; (23) recordkeeping in greenhouse management; and (24) legal considerations. The instructor materials include 24 student objectives; 24 competencies; suggestions for motivating students; evaluation suggestions; 38 references; a competency profile on which to record student performance; transparency masters; job sheets; assignment sheets; and appendices that contain a production schedule for potted plant crops and crop culture sheets for nine common greenhouse crops (chrysanthemums, foliage plants, bedding plants, Easter lilies, tulips, geraniums, calceolaria, cineraria, and poinsettias). The student reference includes information sheets for the 24 lessons that contain text, line illustrations, diagrams, and references. The student reference concludes with a two-page glossary. (CML)

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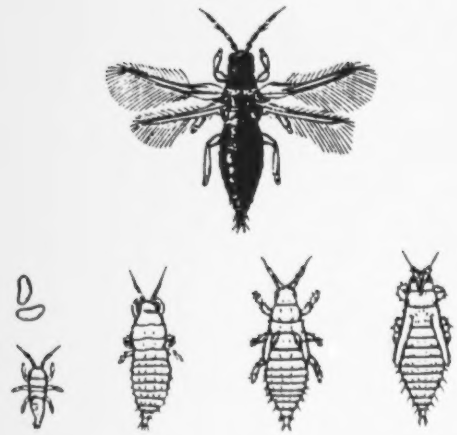
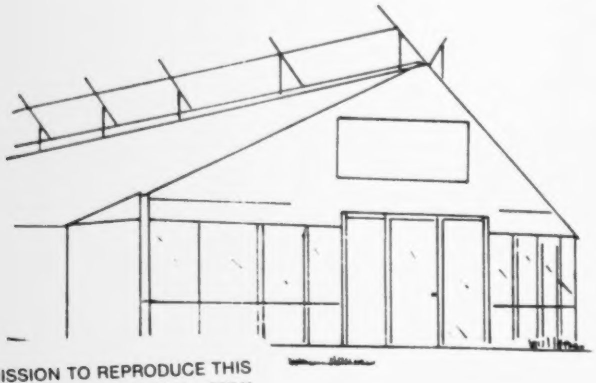
Greenhouse Operation and Management

Instructor Guide





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The activity which is the subject of this report was supported in whole or in part by funds from the Department of Elementary and Secondary Education, Division of Vocational and Adult Education. However, the opinions expressed herein do not necessarily reflect the position or policies of the Missouri Department of Elementary and Secondary Education or the Division of Vocational and Adult Education, and no official endorsement should be inferred.

Instructor Guide

GREENHOUSE OPERATION AND MANAGEMENT

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Volume 21
Number 3

Catalog Number 10-2010-I
January, 1990

ACKNOWLEDGEMENTS

Recognition is given to advisory committee members for providing their valuable time and suggestions in developing this unit. The committee consisted of Ralph Ball, Jim Bellis, Steven King, Delbert Lund, Robert Mareth, Bob McConnell, Richard McConnell, Barbara Rothenberger, Ramona Schescke, and David Trinklein.

Special recognition is given to Barbara Rothenberger for writing a portion of the material. Some illustrations were prepared by Dodge Art Works, Columbia.

Appreciation is expressed to the following staff members of the Instructional Materials Laboratory for their efforts in producing this material: Harley Schlichting, Director; Amon Herd, Associate Director; Phyllis Miller, Assistant Director; Dan Stapleton, Assistant Director; Crystal Dietiker, Graphic Artist II; Christen Heitkamp and Lori Holliday, Word Processors; Barbara Tidquist, Graduate Technical Assistant; and Karen Omer and Janece Seward, Editorial Assistants.

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FOREWORD

The development of the Greenhouse Operation and Management guide is the result of suggestions by the MVATA Teaching Aids Committee. The Greenhouse Operation and Management Advisory Committee suggested the topics to be discussed and reviewed the materials.

This instructor guide and the corresponding student reference contain 24 lessons, which cover a wide range of topics including: greenhouse structures, greenhouse environmental control, plant processes, growth regulation, growing media, pests, pesticide safety, and record keeping. See the table of contents for a detailed listing. This material is designed to be taught to juniors and seniors as a semester course, but it could easily be adapted to a year course. Transparency masters, job sheets, and assignment sheets have been included where appropriate. A production schedule for potted plant crops has been included as Appendix A. Appendix B includes crop culture sheets for nine common greenhouse crops.

During the summer of 1981, the Missouri State Board of Education formally adopted the concept of "Instructional Management Systems" (IMS) as a priority for the 1981-82 school year. The Missouri Commissioner of Education described the IMS concept as a practical way of "organizing for excellence" in education. To meet the demand for greater productivity and accountability, Dr. Frank Drake, Director of Vocational Education, applied the elements of IMS to form the Vocational Instructional Management System (VIMS). The VIMS process provides a framework to use in planning and organizing to assure excellence in Missouri's vocational education system by focusing greater attention on the management of teaching and learning.

This guide incorporates the needed component parts to aid agriculture teachers in the implementation of VIMS. For ease of use, performance objectives and competencies have been included at the beginning of the unit, as well as being incorporated within each lesson. A competency profile has been provided for convenient record keeping.

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GREENHOUSE OPERATION AND MANAGEMENT

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OBJECTIVES

1. The student will be able to recognize the scope and development of the greenhouse (floriculture) industry.

2. The student will be able to describe the economic importance of greenhouse crops grown in Missouri.

3. The student will be able to recognize career opportunities in the greenhouse industry.

4. The student will be able to identify different greenhouse parts, structures, and coverings.

5. The student will be able to describe the operation of environmental controls and equipment found in a greenhouse such as ventilation, heating, cooling, air circulation, and irrigation.

6. The student will be able to analyze suitable interior layouts, according to greenhouse purpose.

7. The student will be able to describe different modifications and procedures used to conserve energy in greenhouses.

8. The student will be able to identify plant parts, structures, and functions.

9. The student will be able to describe the processes involved with plant growth.

10. The student will be able to describe environmental effects on plant growth.

11. The student will be able to identify the effects that pruning and chemical growth regulators have on plant development.

12. The student will be able to identify plants important to the Missouri floriculture industry.

13. The student will be able to start plants from seeds.

14. The student will be able to start plants by asexual propagation (vegetative techniques).

15. The student will be able to prepare a soilless growing medium.

16. The student will be able to identify the basic types and sizes of container used in the commercial greenhouse.

17. The student will be able to describe the various factors involved in the proper watering of greenhouse plants.

18. The student will be able to describe the principles and techniques for proper fertilization of greenhouse crops.

19. The student will be able to identify common pests and diseases found in greenhouses.

20. The student will be able to describe control methods, chemical formulations, and equipment used to control pests in the greenhouse.

21. The student will be able to identify safety guidelines for pesticide use.

22. The student will be able to prepare a plant for sale.

23. The student will be able to describe various greenhouse records.

24. The student will be able to describe the relevance of the United States Plant Protection Act and the Missouri Plant Law.

NOTE: Percent of accuracy should be set by instructors to reflect passing grades within their school systems.

COMPETENCIES

1. Recognize the scope and development of the greenhouse (floriculture) industry.

2. Describe the economic importance of greenhouse crops grown in Missouri.

3. Recognize career opportunities in the greenhouse industry.

4. Identify different greenhouse parts, structures, and coverings.

5. Describe the operation of environmental controls and equipment found in a greenhouse.

6. Analyze suitable interior layouts according to greenhouse purpose.

7. Describe different modifications and procedures used to conserve energy in greenhouses.

8. Identify plant parts, structures, and functions.

9. Describe the plant processes involved with plant growth.

10. Describe environmental effects on plant growth.

11. Identify the effects that pruning and chemical growth regulators have on plant development.

12. Identify plants that are important to the Missouri floriculture industry.

13. Start plants from seeds.

14. Start plants by asexual propagation methods.

15. Prepare a soilless growing medium.

16. Identify the basic types and sizes of containers used in the commercial greenhouse.

17. Describe the factors involved in the proper watering of greenhouse plants.

18. Describe the principles and techniques for proper fertilization of greenhouse crops.

19. Identify common pests and diseases found in Missouri greenhouses.

20. Describe control methods, chemical formulations, and equipment used to control pests in the greenhouse.

21. Identify safety guidelines for pesticide use.

22. Prepare a plant for sale.

23. Describe the various types of records kept in a greenhouse business.

24. Describe the relevance of the United States Plant Protection Act and the Missouri Plant Law.

MOTIVATIONAL TECHNIQUE OR INTEREST APPROACH

1. Have students write to seed companies for free seed samples and information. Samples can be used later to illustrate plant propagation.

   a. A. H. Hummert Seed Co.
   2746 Chauteau Ave.
   St. Louis, MO 63103

   b. Ball Seed Co.
   P.O. Box 335
   West Chicago, IL 60185

   c. Grimes Seed Co.
   201 West Main Street
   Box 398
   Smethport, PA 16749

   d. Park Seed Co.
   Cokesbury Road
   Greenwood, S.C. 29647-0001

   e. Stokes Seed Co.
   Buffalo, N.Y. 14240

   f. Thompson & Morgan Seed Co.
   P.O. Box 1308
   Jackson, N.J. 08527

   g. W. Atlee Burpee and Co.
   Warminister, PA 18974

2. Tour a local wholesale or retail greenhouse. Have the owner or manager point out the types of plants being grown.

EVALUATION

1. Give short, objective tests following each lesson and a more in-depth objective test at the conclusion of the unit.

2. Observe the changes in behavior as evidence of an improved ability of students to deal with problems in this unit using background information acquired from earlier units.

3. Observe students' attempts to solve similar problems in their supervised agricultural experience programs.

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    b) GO1916: Pesticide Application Safety, n.d.
    c) GO1917: Personal Protective Equipment for Working with Pesticides, n.d.
    d) GO1918: Homeowner Chemical Safety, n.d.
    e) GO6511: Care of Several Flowering Potted Plants I, n.d.
    f) GO6560: Home Propagation of House Plants, 1986.
    g) GO6570: Starting Plants from Seeds, n.d.
    h) GO6970: Home Propagation of Garden and Landscape Plants, 1985.
    i) GO6971: Grafting, 1985.
    j) GO6972: Budding, 1985.

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GREENHOUSE OPERATION AND MANAGEMENT
Major Competency Profile

Directions: Evaluate the student by checking the appropriate number or letter to indicate the degree of competency. The rating for each task should reflect **employability readiness** rather than the grades given in class.

Rating Scale: **3 Mastered** - can work independently with no supervision
2 Requires Supervision - can perform job completely with limited supervision
1 Not Mastered - requires instruction and close supervision
N No Exposure - no experience or knowledge in this area

3	2	1	N	UNIT - GREENHOUSE OPERATION AND MANAGEMENT
				1. Recognize the scope and development of the greenhouse (floriculture) industry.
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				24. Describe the relevance of the United States Plant Protection Act and the Missouri Plant Law.
				______________________________
				______________________________

Greenhouse Operation and Management

Class/Section:

Students:

1. Recognize the scope and development of the greenhouse(floriculture) industry.
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UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 1: History - Scope and Development

Objective: The student will be able to recognize the scope and development of the greenhouse (floriculture) industry.

Study Questions

1. **What is the derivation of "horticulture" and the four divisions of horticulture?**
2. **How did the greenhouse industry evolve and develop?**
3. **What is the importance of greenhouse operations in Missouri?**
4. **What is the importance of greenhouse operations in the United States?**
5. **What is the importance of greenhouse operations in the world?**
6. **What are the top seven states in floriculture production?**
7. **What are the five leading states in each production category?**

References

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2. Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987. (Instructors should obtain an updated yearly report from the USDA.)
3. Transparency Master
    a) TM 1.1: Major Greenhouse Production States
4. Assignment Sheet
    a) AS 1.1: Major Greenhouse Production States

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 1: History - Scope and Development

TEACHING PROCEDURES

A. Introduction

Introduce the unit. At this time, the teacher may also want to tour the facilities with the students and discuss class policies and safety rules.

B. Motivation

In order to understand the greenhouse (floriculture) industry, it is important to be familiar with its past, present, and future. This lesson will examine how the greenhouse industry fits into the four divisions of horticulture. The major greenhouse production areas, the history and development of the greenhouse industry, and the importance of greenhouse operations in Missouri, the United States, and the world will be explored.

C. Assignment

D. Supervised study

E. Discussion

1. Ask the students: What is horticulture? What does it mean? Write the words horticulture, pomology, olericulture, ornamental, and floriculture on the board and show how they can be divided into two words. Ask students to discuss what types of plants could be included in a garden.

   What is the derivation of "horticulture" and the four divisions of horticulture?

   a) Horti/culture meaning "garden"/"cultivation"
   b) The four divisions of horticulture
      1) Pom/ology meaning "fruit"/"the study of"
      2) Oleri/culture meaning "vegetables"/"cultivation"
      3) Ornamental meaning plants grown for their beauty
      4) Flori/culture meaning "flowers"/"cultivation"

2. Have students discuss the history, evolvement, and development of the greenhouse industry. Discuss how transportation and market areas relate to the development of the greenhouse industry.

   How did the greenhouse industry evolve and develop?

   a) First century A.D. Roman emperors used "specularia" to protect tender plants.
   b) In the 13th century, Albertus Magnus, a Dominican monk, was charged with witchcraft for attempting to force flowers to bloom out of their natural season.
   c) "Orangeries" were built in the 17th century. At Heidelberg, Germany, in 1619 one orangery contained 40 mature and 300 small citrus trees.
   d) "Conservatories" that were popular in Victorian England contained exotic tropical flowering and foliage plants brought home by English explorers.
   e) Around 1710 the first documented greenhouse in the United States was built by Andrew Faneuil on the estate of Governor Bellingham in Boston, Massachusetts.
   f) In 1780 less than 100 florists were in production in the United States. They had to be close to the market area.
   g) By 1880, although they were still located close to the market areas, almost 5,000 commercial greenhouse ranges were in operation.

h) With improved transportation, in 1950 growers began to market products over a much larger distance, although container-grown plants remained a locally produced crop.
i) By 1966 better transportation enabled growers to move production of carnations to Bogota, Colombia in South America. Chrysanthemums and roses were also being imported from South America.
j) In the 1980s Dutch growers specialize in a single crop or related crops, have highly automated production, and market crops by the auction market system. The Netherlands exports products to the United States.

3. Have students list what floriculture crops are produced locally. Discuss what floriculture crops are available during the year at the local markets. Discuss the importance of greenhouse operations in Missouri.

What is the importance of greenhouse operations in Missouri?

a) They grow a variety of products: cut flowers, container-grown flowering plants, foliage plants, and bedding plants.
b) They provide employment opportunities. There were 121 Missouri growers, each earning an annual gross income of $10,000 or more, in 1986. Missouri greenhouse production area totals nearly five million square feet of growing space.
c) They contribute to Missouri's income. In 1986, the wholesale value of the state's floriculture crops was $26 million.

4. Have students discuss what floriculture crops are produced in the United States. Discuss the importance of greenhouse operations in the United States.

What is the importance of greenhouse operations in the United States?

a) They grow a wide variety of products: bedding plants, foliage plants, container-grown flowering plants, cut flowers, and cut cultivated greens.
b) They provide employment opportunities. There are 6,907 growers in the United States with a total production area of 341 million square feet of growing space.
c) They contribute to the nation's income. In 1986, the wholesale value of U.S. floriculture crops was $1.88 billion.

5. Discuss with the students the importance of greenhouse operations in the world.

What is the importance of greenhouse operations in the world?

a) They grow a wide variety of products: cut flowers, container-grown flowering plants, foliage plants, bedding plants, and cut cultivated greens.
b) They provide employment opportunities.
c) They contribute to the world's income.
d) Floriculture crops will always be in demand because they fulfill an emotional need in human beings; they are very effective for use in horticultural therapy activities.
e) European countries are important because they are the most advanced in flower marketing procedures, as well as leading the world in incorporation of floriculture crops into daily life.

6. Have students list the top seven states in floriculture production and discuss the reasons those states are more favorable for plant production than others.

What are the top seven states in floriculture production?

a) Florida
b) California
c) Ohio
d) Pennsylvania
e) Michigan

   - f) New York
   - g) Texas

7. Each floriculture crop is listed in order of economic importance. Point out that although Florida leads overall in floriculture production, California leads in three out of five crops. Discuss with students how that is possible. The instructor could use TM 1.1 to mark the leading states in floriculture production of each crop. The instructor may want to use a different colored marker for each category of plants or use a lettering system as illustrated in the answer to the assignment sheet. Have students complete AS 1.1.

   What are the five leading states in each production category?

   a) Cut flower production
      1) California
      2) Florida
      3) Colorado
      4) Hawaii
      5) Pennsylvania
   b) Container-grown flowering plant production
      1) California
      2) Florida
      3) New York
      4) Pennsylvania
      5) Ohio
   c) Foliage plant production
      1) Florida
      2) California
      3) Texas
      4) Ohio
      5) Hawaii
   d) Bedding plant production
      1) California
      2) Ohio
      3) Michigan
      4) Florida
      5) Pennsylvania
   e) Cut cultivated greens production
      1) Florida
      2) California
      3) Hawaii
      4) Texas
      5) Indiana

F. Other activity

Invite a local greenhouse operator to discuss the floriculture crops grown in his or her greenhouse.

G. Conclusion

Floriculture (i.e., the cultivation of cut flowers, container-grown flowering plants, foliage plants, bedding plants, and cut cultivated greens) is one of the four divisions of horticulture. Most floriculture crops are greenhouse-grown, with a wholesale value of $26 million in Missouri and $1.88 billion in the United States during 1986. The floriculture industry provides a vast array of products, employment opportunities, income potential, and an effective means for horticultural therapy activities.

H. Competency

Recognize the scope and development of the greenhouse (floriculture) industry.

I. Answers to Evaluation

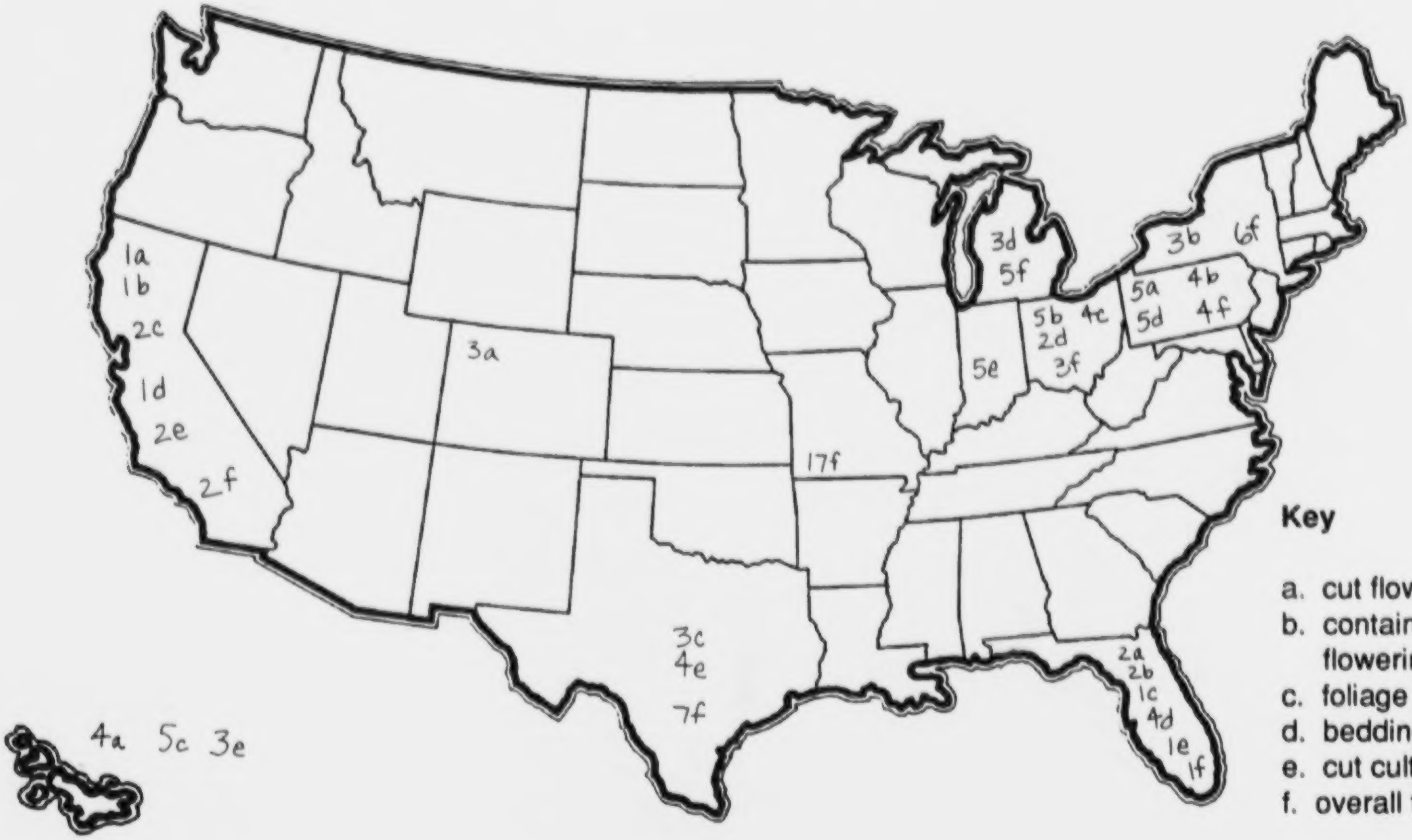
1. c
2. a
3. d
4. e
5. b
6. d
7. c
8. d
9. Any two of the following:
    a) They grow a variety of products: cut flowers, container-grown flowering plants, foliage plants, and bedding plants.
    b) They provide employment opportunities.
    c) They contribute to Missouri's income.
10. Florida, California, Ohio, Pennsylvania, Michigan, New York, and Texas

J. Answers to AS 1.1

The answer to this assignment sheet is on the following page. The key explains the lettering system used. For example, 3c located in Texas indicates that Texas is ranked third in the production of foliage plants.

TM 1.1
AS 1.1

Major Greenhouse Production States


1a
1b
2c
1d
2e
2f
3a
3d
5f
3b
6f
5a
4b
5d
4f
5b
4c
2d
3f
5e
17f
3c
4e
7f
4a
5c
3e
2a
2b
1c
4d
1e
1f

Key

a. cut flower
b. container-grown flowering plant
c. foliage plant
d. bedding plant
e. cut cultivated greens
f. overall floriculture

Rank Number Order

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ________________

Lesson 1: History - Scope and Development Date ________________

EVALUATION

Match the definition on the right with the term on the left.

___ 1. horticulture	a. the science and practice of growing, harvesting, handling, storing, processing, and marketing of fruits
___ 2. pomology	b. the science and practice of growing, harvesting, storing, designing, and marketing flowering plants
___ 3. olericulture	c. the cultivation, processing, and sales of fruits, nuts, vegetables, ornamental plants, and flowers
___ 4. ornamental	d. the science and practice of growing, harvesting, storing, processing, and marketing of vegetables
___ 5. floriculture	e. the science and practice of propagating, growing, maintaining, and using a plant grown for its beauty

Circle the letter that corresponds to the best answer.

6. The _________ devised the first greenhouses or "specularia" in the ________.

   a. Americans, 1700s
   b. Americans, 1800s
   c. English, 1800s
   d. Romans, first century A.D.

7. Floriculture crops produced in the United States in 1986 had the wholesale value of ______________.

   a. $26 million
   b. $89 million
   c. $1.88 billion
   d. $2.3 billion

8. Which of the following floriculture crops are produced in Missouri?

   a. Cut flowers and cut cultivated greens
   b. Cut flowers, bedding plants, and foliage plants
   c. Cut flowers, foliage plants, and cut cultivated greens
   d. Cut flowers, container-grown flowering plants, foliage plants, and bedding plants

Complete the following short answer questions.

9. State two reasons why greenhouse operations are important in Missouri.

10. List the top seven states in floriculture production.

TM 1.1
AS 1.1

Major Greenhouse Production States

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 2: Economic Importance of Greenhouse Crops

Objective: The student will be able to describe the economic importance of greenhouse crops grown in Missouri.

Study Questions

1. **What is the value of greenhouse crops grown in Missouri?**
2. **What percentage of U.S. floriculture crops is grown in Missouri?**
3. **What are the estimated costs of operating the average Missouri greenhouse in 1988?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987. (The instructor should obtain an up-to-date copy from the USDA.)
3. Transparency Masters
    a) TM 2.1: Floriculture Crops Produced in Missouri
    b) TM 2.1 (cont.)
    c) TM 2.2: Estimated Cost Analysis
4. Assignment Sheet
    a) AS 2.1: Floriculture Crops Produced in Missouri

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 2: Economic Importance of Greenhouse Crops

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

Missouri ranks 17 out of 28 states in the production of floriculture crops. The potential for floriculture production in Missouri is starting to be realized. Greenhouse crop production opportunities are great.

C. Assignment

D. Supervised study

E. Discussion

1. Ask the students where Missouri ranks in the production of floriculture crops. Ask if any of the students know the wholesale value of floriculture crops produced in Missouri. Have students look at Table 2.1 in the student reference and answer the questions on AS 2.1. Table 2.1 gives the overall production picture of the floriculture industry in Missouri, as well as a financial analysis for each major crop.

   What is the value of greenhouse crops grown in Missouri?

   a) In 1986, the total wholesale value of floriculture crops produced in Missouri was $26 million.
   b) In 1986, Missouri was ranked 17th in amount of floriculture crops grown.

2. Discuss the percentage of floriculture crops that are grown and the top ranking floriculture crops that are produced in Missouri. Use TM 2.1.

   What percentage of U.S. floriculture crops is grown in Missouri?

   a) In 1986, Missouri produced nearly 1.4 percent of floriculture crops grown in the United States, or $26 million of the total $1.88 billion.
   b) Seventy-one percent or 20 of the 28 floriculture crops reported are grown in Missouri.

3. Discuss with students the various costs involved with the total production cost of floriculture crops. Use TM 2.2. The greenhouse industry is a very labor-intensive business. Ask students what percentage of the total production costs is related to labor. The answer below gives the percentage of the total cost for each cost.

   What are the estimated costs of operating the average Missouri greenhouse in 1988?

   a) Labor - 33 percent
   b) Fuel - 25 percent
   c) Marketing/selling - 15 percent
   d) Cultural supplies - 12 percent
   e) Depreciation - 5 percent
   f) Maintenance/repair - 4 percent
   g) Other items - 6 percent

F. Other activities

1) Invite a local wholesale greenhouse operator to discuss how his or her expenses compare with those listed in this lesson.

2) Invite a local grower to discuss the financial management of his or her greenhouse.

G. Conclusion

Missouri produced wholesale floriculture crops valued at $26 million in 1986 for nearly 1.4 percent of the total United States floriculture crop production. Labor and energy costs rank as the top two greenhouse operating expenses.

H. Competency

Describe the economic importance of greenhouse crops grown in Missouri.

I. Answers to Evaluation

1. c
2. a
3. b
4. d
5. c

J. Answers to AS 2.1

1. Other flowering or foliar type bedding plants (flats)
2. 699,000
3. Poinsettia
4. 1,000
5. Carnations, standard
6. Bedding geraniums (flats)
7. Carnations, standard
8. Other flowering or foliar type bedding plants (flats)
9. Other flowering or foliar type bedding plants (flats)
10. Other cut flowers

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Name ____________________

Lesson 2: Economic Importance of Greenhouse Crops

Date ____________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Missouri ranks _______________ in the production of floriculture crops.

   a. 1st
   b. 12th
   c. 17th
   d. 25th

2. What was the total wholesale value of floriculture crops produced in Missouri for 1986?

   a. $26 million
   b. $52 million
   c. $1.8 billion
   d. This amount has not been determined

3. Missouri produces what percentage of the floriculture crops grown in the United States?

   a. Less than 1 percent
   b. Nearly 1.4 percent
   c. 5.3 percent
   d. 17 percent

4. _________________ is the leading container-grown flowering plant produced in Missouri.

   a. Azalea
   b. Easter lily
   c. Chrysanthemum
   d. Poinsettia

5. What is the largest single cost of the items included in total production costs?

   a. Cultural supplies
   b. Heating
   c. Labor
   d. Upkeep and repair

Floriculture Crops Produced in Missouri

Rank	Floriculture Crop	Wholesale Value in Thousands
Cut Flowers		
1.	Mums, glads, and roses	$1,001
2.	Carnations, standard	15
3.	Other cut flowers	30
	Total Cut Flowers Produced in Missouri	$1,046
Container-Grown Flowering Plants		
1.	Poinsettias	$2,880
2.	Mums	1,527
3.	Easter lilies	755
4.	Azaleas	257
5.	African violets	153
6.	Other lilies	133
7.	Other flowering plants	2,613
	Total Container-Grown Flowering Plants	$8,318

Foliage Plants

1.	Potted foliage	$1,871
2.	Hanging baskets	656
	Total Foliage Plants	$2,527

Bedding/Garden Plants

1.	Bedding plants (flats excluding those listed below)	$7,411
2.	Vegetable type bedding plants (flats)	2,167
3.	Flowering hanging baskets	1,260
4.	Potted geraniums (cuttings)	1,062
5.	Potted geraniums (seed)	700
6.	Potted hardy/garden mums	662
7.	Bedding geraniums (flats)	582
8.	Potted vegetable type bedding plants	29
9.	Other potted flowering and foliar type bedding plants	368
	Total Bedding Plants	$14,241
	Total Wholesale Value of Floriculture Crops Produced in Missouri During 1986	$26,177

Credit: Agricultural Statistics Board. **Floriculture Crops 1986 Summary.** Washington, DC: United States Department of Agriculture, 1987.

Estimated Cost Analysis*

Expense	**Percent of Total Expense**
Labor	33
Fuel	25
Marketing/selling	15
Cultural supplies	12
Depreciation	5
Maintenance/repair	4
Other items	6
TOTAL	**100**

* Based on the average sized Missouri greenhouse business during 1987.

FLORICULTURE CROPS PRODUCED IN MISSOURI

Directions: Refer to Table 2.1 in the student reference to answer the following questions.

1. Which floriculture crop has the largest number of commercial growers in Missouri?

2. How many containers of poinsettias were sold in 1986 in Missouri?

3. What container-grown flowering plant required the largest total production area?

4. How many Easter lilies were produced in a container less than 5 inches?

5. Which floriculture crop had the lowest percentage of sales at wholesale?

6. Which floriculture crop had the greatest wholesale price per plant?

7. Which floriculture crop was marketed at the lowest wholesale price?

8. Which floriculture crop has the greatest value of sales at wholesale?

9. Which floriculture crop was projected to increase in sales the most?

10. Which floriculture crop had the highest percentage of sales at the wholesale level?

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 3: Careers

Objective: The student will be able to recognize career opportunities in the greenhouse industry.

Study Questions

1. **What are the differences between a grower, wholesaler, and retailer?**
2. **What is the management structure of a greenhouse business?**
3. **What are some career opportunities in the greenhouse industry?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. "Careers in Ornamental Horticulture." Tape/Filmstrip. Vocational Education Productions, 1-901-135H, 1988.
3. Transparency Masters
    - a) TM 3.1: Management Structures for Greenhouse Operations
    - b) TM 3.2: Career Ladder

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 3: Careers

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

There are many career opportunities in the greenhouse industry. Achievement of goals depends on wise planning. Here is a look at some of the opportunities in the greenhouse industry.

C. Assignment

D. Supervised study

E. Discussion

1. Ask the students to discuss the differences between grower, wholesaler, and retailer. Discuss who the products are being sold to at each level. Not all greenhouse operations will fit neatly in a specific category. For example, a grower may market his or her plants instead of selling them to the wholesaler.

What are the differences between a grower, wholesaler, and retailer?

a) Grower
    1) Produces crops for sale to the wholesale level
    2) Develops expertise in the production of one or more crops
    3) Generally leaves marketing to the wholesaler
b) Wholesaler
    1) Sells a wide range of floriculture crops and products to retail businesses
    2) May sell flowers and plants on consignment from the growers
    3) Serves as a supermarket for the retailers to buy supplies
c) Retailer
    1) Sells products to the general public
    2) Is located in preferred retail marketing areas
    3) Includes many types of businesses
        (a) Florist shops
        (b) Retail greenhouses - produce small quantities of a large selection of flowers and/or plants continuously
        (c) General retail stores

2. Discuss with students the management structure of a greenhouse business. TM 3.1 illustrates the differences between the management structure found in a single-manager verses a multiple-manager business. Discuss with students the departments within the greenhouse business and the responsibilities for each department.

What is the management structure of a greenhouse business?

a) One-manager business
    1) The manager, usually the owner, is responsible for all departments in the greenhouse.
    2) There may be workers under the manager who are assigned duties.
b) Multiple-manager business
    1) The general manager oversees the overall operation of the business. The general

manager may or may not be the owner.

2) Usually there will be department managers for business procedures, engineering, production, and marketing.

3) Workers may be assigned to each department.

3. Discuss with students the career opportunities in the greenhouse industry. Table 3.1 in the student reference gives detailed information about the careers in the greenhouse industry. Use TM 3.2 to illustrate the greenhouse industry career ladder.

What are some career opportunities in the greenhouse industry?

a) Grower assistant
    1) Responsibilities: helps the grower perform tasks; may also work in maintenance or shipping
    2) Education: high school student enrolled in horticulture or high school graduate
    3) Work experience: strong interest in crop production

b) Grower
    1) Responsibilities: responsible for production practices for specific crops; all physical labor involved with producing a crop: soil preparation, planting, fertilizing, watering, etc.
    2) Education: high school graduate preferably with vocational or technical training in horticulture or B.S. in horticulture
    3) Work experience: 2 years as a grower's assistant

c) Engineering manager
    1) Responsibilities: maintains all physical facilities, supervises maintenance crews, plans work schedules, orders materials, and keeps records of scheduled jobs
    2) Education: high school graduate preferably with vocational or technical training
    3) Work experience: strong background in mechanical or agricultural engineering; knowledge of crop production

d) Production manager
    1) Responsibilities: in charge of growing the crops; assigns duties and responsibilities to growers and assistant growers; orders all plant materials and supplies
    2) Education: B.S. or A.A. in horticulture
    3) Work experience: several years experience as a grower; knowledge of cultural techniques and marketing trends

e) Marketing manager
    1) Responsibilities: in charge of grading, postharvest handling and storage, packing and shipment of plants and flowers; orders cartons, containers, and packing materials for each crop; oversees sales, finds new customers, and maintains contact with established customers
    2) Education: B.A. in business, marketing, or business administration
    3) Work experience: previous business experience; familiar with the greenhouse operation

f) Business procedure manager
    1) Responsibilities: in charge of payroll, correspondence, accounts receivable, purchasing, and accounts payable; supervises clerical help
    2) Education: B.A. in accounting or business administration
    3) Work experience: previous business experience

g) General manager or owner
    1) Responsibilities: in charge of the total greenhouse business; assigns duties and responsibilities to others; coordinates production, marketing, engineering, and business procedures
    2) Education: B.S. in horticulture
    3) Work experience: 5 years practical experience in crop production techniques, business principles, and personnel management

F. Other activities

1. Have students use the telephone book to make a list of horticulture businesses in the local community.

2. Invite a local greenhouse grower to speak to the class on career opportunities in the greenhouse industry and what they look for in a potential employee.

3. Have students interview persons who are employed in the greenhouse industry and report about their findings to the class.

G. Conclusion

Greenhouse management structures will vary according to the size of the operation and according to its purpose (i.e., grower, wholesaler, or retailer). Currently, many career opportunities exist in the greenhouse industry.

H. Competency

Recognize career opportunities in the greenhouse industry.

I. Answers to Evaluation

1. a
2. c
3. b
4. b
5. b
6. a
7. c
8. a
9. d
10. b
11. b

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ____________________

Lesson 3: Careers Date ____________________

EVALUATION

Match the three levels of greenhouse businesses on the right with what they do on the left.

____ 1. expert in the production of one or more crops

____ 2. produces a small portion of own merchandise continuously

____ 3. sells a wide range of crops and products

____ 4. may sell on consignment

____ 5. sells to the retailer

____ 6. sells to the wholesaler

____ 7. sells to the general public

a. grower

b. wholesaler

c. retailer

Circle the letter that corresponds to the best answer.

8. The individual responsible for the physical labor involved in producing a crop is which of the following?

   a. Grower
   b. Grower assistant
   c. Marketing manager
   d. Production manager

9. A(n) __________ is responsible for assigning duties to growers and grower assistants.

   a. Business procedure manager
   b. Engineering manager
   c. Marketing manager
   d. Production manager

10. The individual responsible for the maintenance of the greenhouse is which of the following?

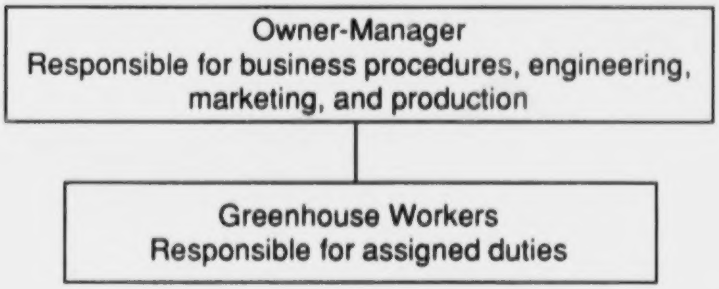
   a. Business procedure manager
   b. Engineering manager
   c. Marketing manager
   d. Production manager

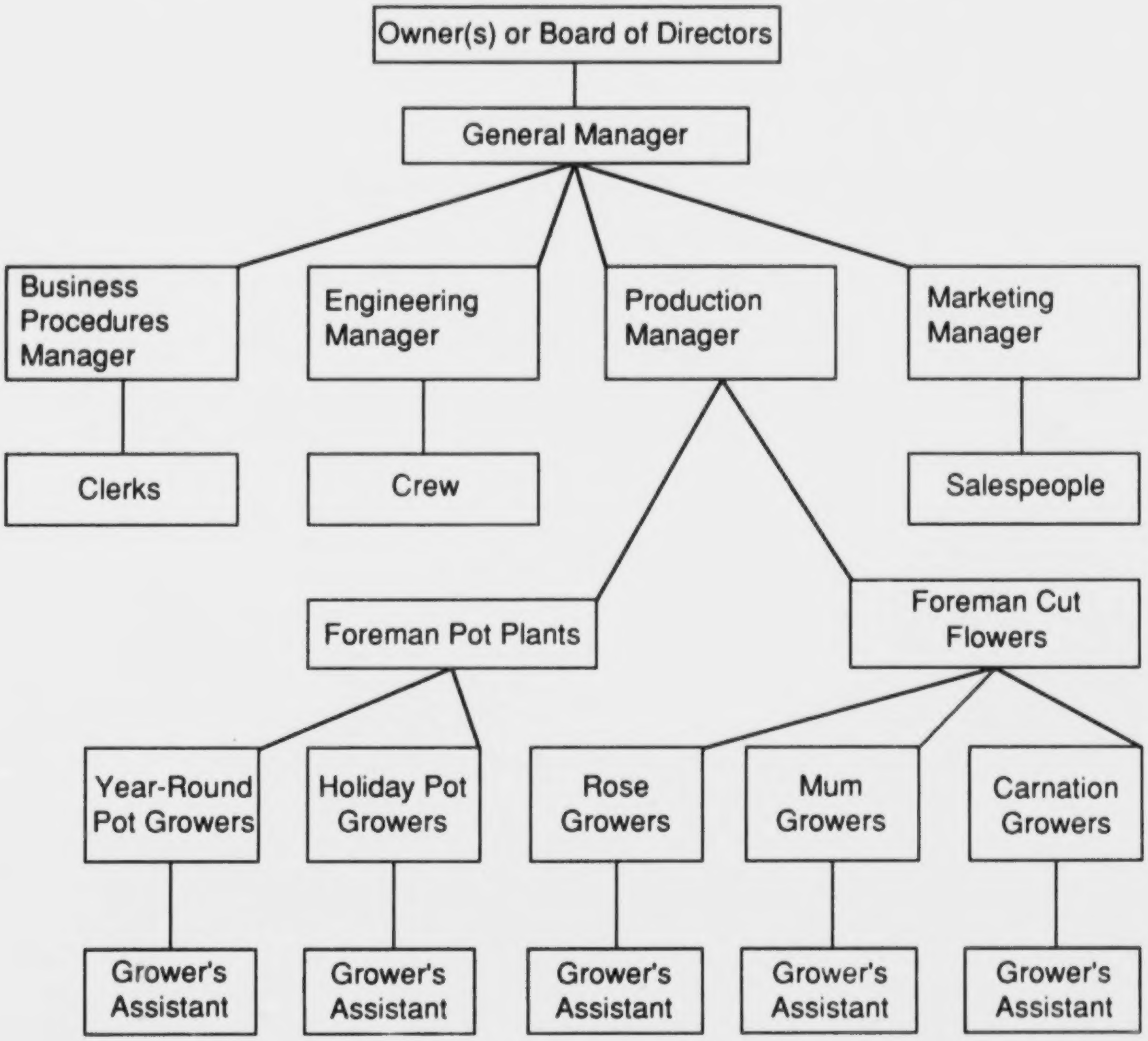
11. An individual with experience in agricultural mechanics might obtain a position in a greenhouse in which of the following areas?

   a. Business procedures
   b. Engineering
   c. Marketing
   d. Production

TM 3.1

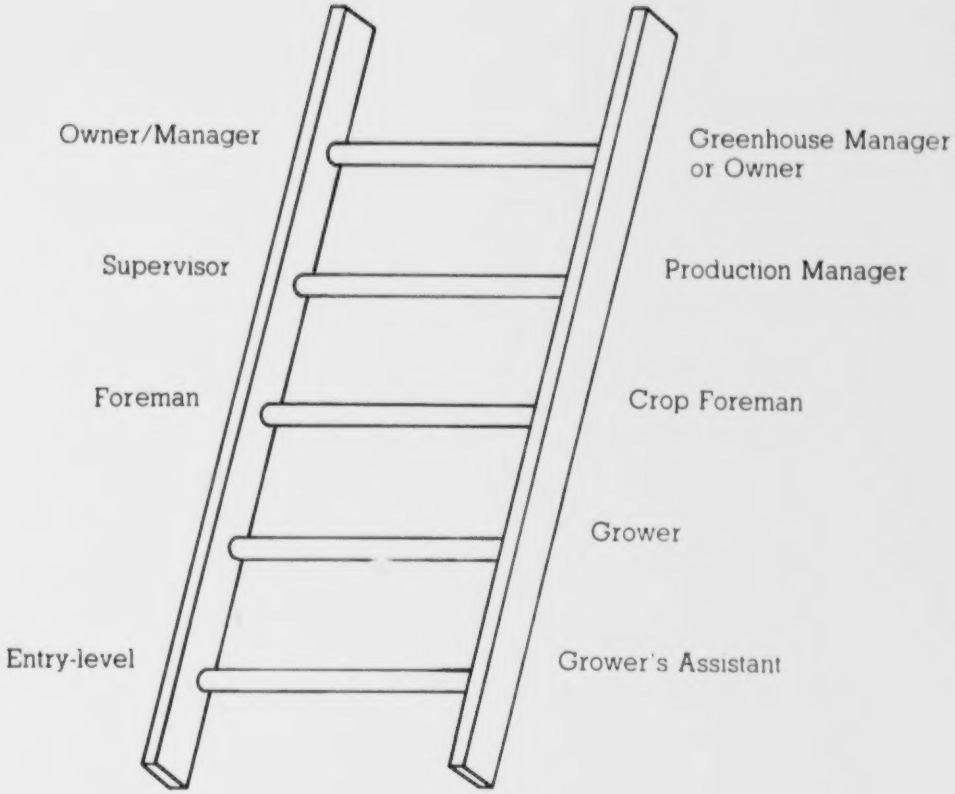
Management Structures For Greenhouse Operations


Owner-Manager
Responsible for business procedures, engineering, marketing, and production
Greenhouse Workers
Responsible for assigned duties


Owner(s) or Board of Directors
General Manager
Business Procedures Manager
Engineering Manager
Production Manager
Marketing Manager
Clerks
Crew
Salespeople
Foreman Pot Plants
Foreman Cut Flowers
Year-Round Pot Growers
Holiday Pot Growers
Rose Growers
Mum Growers
Carnation Growers
Grower's Assistant
Grower's Assistant
Grower's Assistant
Grower's Assistant
Grower's Assistant

TM 3.2

Career Ladder


Owner/Manager
Greenhouse Manager or Owner
Supervisor
Production Manager
Foreman
Crop Foreman
Grower
Entry-level
Grower's Assistant

Each step requires increased skill and experience.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 4: Greenhouse Parts, Structures, and Coverings

Objective: The student will be able to identify different greenhouse parts, structures, and coverings.

Study Questions

1. **What is a greenhouse?**
2. **What are the characteristics of the major types of greenhouses?**
3. **What are the related structures of a greenhouse?**
4. **What are the factors to consider when purchasing a greenhouse covering material?**
5. **What are the characteristics of the major greenhouse covering materials?**
6. **What are the parts of a greenhouse?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. "Building and Using Hotbeds and Coldframes," G06965. University Extension Publications, 115 S. 5th St., Columbia, MO 65211.
3. Transparency Masters
    - a) TM 4.1: Styles of Greenhouses
    - b) TM 4.2: Related Structures
    - c) TM 4.3: Parts of a Greenhouse
4. Assignment Sheet
    - a) AS 4.1: Parts of a Greenhouse

Lesson 4: Greenhouse Parts, Structures, and Coverings

TEACHING PROCEDURES

A. Review

Review the previous lesson.

B. Motivation

It is important for a greenhouse worker to be able to identify the different types of greenhouses and related structures. The different types of covering materials used, the advantages and disadvantages of each, and the structural parts of a greenhouse are all necessary components of a greenhouse.

C. Assignment

D. Supervised study

E. Discussion

1. Ask the students to define a greenhouse. Have the students list the environmental factors that can be controlled in a greenhouse.

What is a greenhouse?

A greenhouse is a structure covered with a transparent or semi-transparent material kept at a controlled temperature, used for the cultivation or protection of plants. Several environmental factors can be controlled in a greenhouse:

a) Temperature
b) Light
c) Water
d) Humidity
e) Plant pests

2. Have the students describe various types of greenhouses and discuss advantages and disadvantages of each. Use TM 4.1.

What are the characteristics of the major types of greenhouses?

a) Lean-to or shed-roof - a greenhouse attached to the east- or south-facing wall of an existing building
   1) Good use of sunlight
   2) Less roof support required
   3) Heat may be supplied by adjacent building
   4) Incorporation of passive solar heating
   5) Limited space
b) Even span or span roof - a greenhouse with two roof slopes of equal pitch and width
   1) Excellent light, ventilation, and temperature control
   2) Better cultural controls possible when in greenhouse range
   3) Increased labor required between individual greenhouses
   4) Wasted heated air in the gables
c) Uneven span - a greenhouse built on a south-facing hill with the short side of the roof on the uphill side
   1) Minimal shadows
   2) Conservation of energy

        3) Natural ventilation to reduce heating and ventilation costs
        4) Difficult to work in
        5) Not adaptable for automation
    d) Quonset - a greenhouse with a semicircular arch that starts at ground level or on top of a sidewall
        1) Economical to construct
        2) Few shadows
        3) Reduced wind and snow load
        4) Wasted area along sidewalls
    e) Dutch - an even span greenhouse with a lower overhead roof and six-foot-high sidewalls
        1) More economical to heat
        2) Better utilization of interior space
        3) Truss types are free of interior support posts
        4) Adaptable to automation
    f) Ridge-and-furrow - several greenhouses connected along the length of the eaves
        1) Maximum use of land
        2) Large interior areas
        3) Adaptable to automation
        4) Reduced heat loss
        5) Less expensive to construct than even span
        6) Difficult snow removal
        7) Increased shading
        8) Poor disease, insect, and temperature control
        9) Fans required

3. Have students describe various structures related to greenhouses and the uses of each. Use TM 4.2.

What are the related structures of a greenhouse?

a) Coldframe - an outdoor unheated growing structure covered with a transparent glazing material
    1) Uses - to harden and protect plants from frost
    2) Heat source - sun
b) Hotbed - an outdoor growing structure similar to a coldframe but heated by an external source
    1) Uses - to start seedlings and root leafy cuttings
    2) Heat sources - steam, hot water, electricity, or manure
c) Lathhouse - an outdoor pole-supported structure covered with lath, polypropylene shade fabric, or other material
    1) Uses - year around production or protection of plants in warm climates or during summer months in temperate climates
    2) Heat source - sun

4. Discuss with students the characteristics which a good covering material for a greenhouse would have.

What are the factors to consider when purchasing a greenhouse covering material?

a) Initial cost
b) Maintenance costs
c) Durability
d) Light transmission
e) Heat retention
f) Superstructure required
g) Water condensation potential
h) Expansion/contraction potential
i) Light diffusion

j) Static electricity charge
k) Availability of materials

5. Have students describe various types of covering materials. Discuss characteristics of each. The instructor may want to contact greenhouse suppliers for samples of greenhouse covering materials.

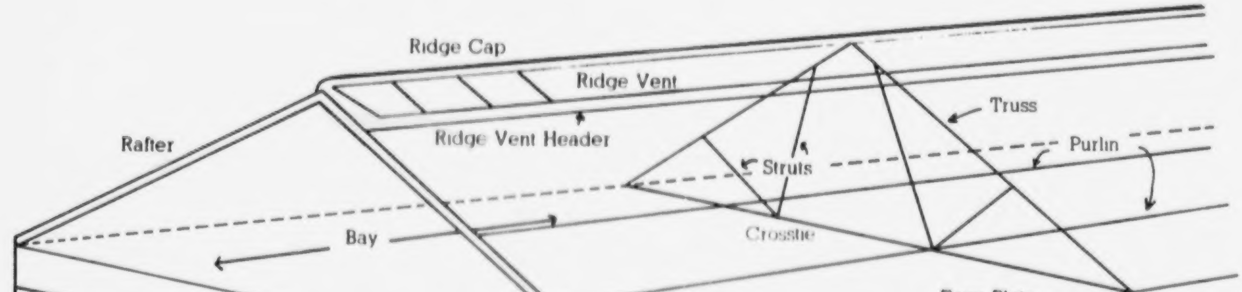
What are the characteristics of the major greenhouse covering materials?

a) Glass - standard B grade, 26-ounce double glass most commonly used
    1) Excellent light transmission
    2) Highest heat loss
    3) Low thermal expansion/contraction
    4) Readily available
    5) Long lasting - 25 years plus
    6) Breakable
    7) High cost
    8) Difficult to install
    9) Requires a superstructure of wood or aluminum
b) Fiberglass - also known as fiberglass reinforced plastic; corrugated panels of glass fibers imbedded in plastic resins
    1) Excellent light transmission
    2) Better light diffusion than glass
    3) Easier to cool than glass
    4) Periodic resurfacing required
    5) Medium to long life - 10-20 years
    6) Cloudy appearance with age
    7) Extremely flammable
    8) High insurance rates
c) Acrylic - also known as Plexiglass®, Lucite®, and Exolite®; manufactured in double-walled sheets
    1) Twice the heat retention of glass
    2) High expansion/contraction potential
    3) Lightweight
    4) Superior resistance to ultraviolet light
    5) No condensation problems
    6) Superior weather resistance
    7) More resistant to impact than glass
    8) Excellent light transmission
    9) High cost
    10) Easily scratched
    11) Flammable
d) Polycarbonate - also known as Lexan®; profiled sheets that have double-walled construction with airspace between walls
    1) Lightweight
    2) High impact resistance
    3) Nonflammable
    4) No condensate drip
    5) Good diffusion
    6) Lower light transmission than acrylic
    7) Similar to acrylic in heat retention
    8) More expensive than acrylic and fiberglass
    9) Limited durability and ultraviolet light resistance
    10) Easily scratched
    11) High expansion/contraction potential
e) Polyvinyl chloride (PVC)
    1) Slightly more durable than polyethylene
    2) More expensive than polyethylene
    3) Available in narrow widths only

    4) Lasts 4-5 years
    5) Static electricity charge which attracts dust, reducing light transmission
    6) High potential for moisture condensation
    7) Resistant to ultraviolet light
    8) Brittle and easily torn in cold weather
    9) Extremely flammable
    10) Not widely used
  f) Polyvinyl fluoride film - also known as Tedlar®
    1) Weather resistant up to 10 years
    2) Excellent light transmission
    3) More expensive than polyethylene
    4) Available only in narrow sheets
    5) Very durable
    6) High installation costs
    7) Resistant to ultraviolet deterioration
  g) Polyethylene
    1) Most common
    2) Least expensive
    3) Available in large sheets
    4) Conservation of energy when double-layered
    5) Good heat retention
    6) High potential for moisture condensation
    7) CO_2 not exchanged readily
    8) Low resistance to ultraviolet light unless treated with UV-inhibitor
    9) Easy to install

6. Discuss with students the parts of a greenhouse. Use TM 4.3.

What are the parts of a greenhouse?


Ridge Cap
Ridge Vent
Truss
Rafter
Ridge Vent Header
Purlin
Struts
Bay
Crosstie
Eave Plate
Sash or Glazing Bars
Girt
Side Ventilator
Transom Sill
Wall Sill
Lower Side Sash
Side Post
Lower Sidewall
Corner Post
Gable End
Side

F. Other activities

1. Make labels for the parts of a greenhouse. Have students locate and tape the labels on the parts of the school's greenhouse.

2. View Greenhouse Maintenance a tape/filmstrip from Vocational Education Productions at California Polytechnic State University, San Luis Obispo, California 93407. 66 frames.

G. Conclusion

Greenhouses are available in many different architectural designs and varying structural components, including a wide selection of covering or glazing materials. Coldframes, hotbeds, and lathhouses are other types of plant-growing structures built outdoors. All of the above factors must be considered when building, purchasing, or even working in a greenhouse.

H. Competency

Identify different greenhouse parts, structures, and coverings.

I. Answers to Evaluation

1. c
2. b
3. a
4. d
5. e
6. d
7. b
8. c
9. a
10. c
11. d
12. d
13. c
14. b
15. a

J. Answers to AS 4.1
1. side ventilator
2. gable end
3. rafter
4. ridge vent header
5. struts
6. column
7. ridge cap
8. eave plate
9. ridge vent
10. side

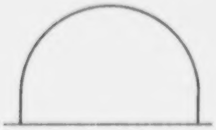
UNIT - GREENHOUSE OPERATION AND MANAGEMENT	Name ____________________

Lesson 4: Greenhouse Parts, Structures, and Coverings	Date ____________________

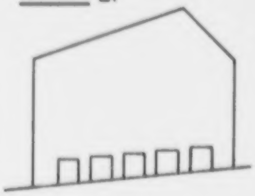
EVALUATION

Match the following greenhouse types with their shapes.

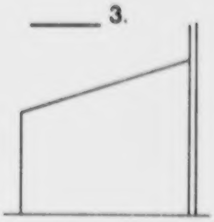
_____ 1.



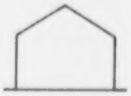
_____ 2.



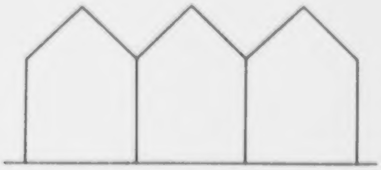
_____ 3.



_____ 4.



_____ 5.



a. Lean-to
b. Uneven span
c. Quonset
d. Dutch
e. Ridge-and-furrow

Circle the letter that corresponds to the best answer.

6. Which of the following is a structure used to control the temperature, light, water, humidity, and plant pests?

   a. Lathhouse
   b. Coldframe
   c. Hothouse
   d. Greenhouse

7. Which of the following is not a factor to be considered when purchasing a greenhouse covering material?

   a. Durability
   b. Light reflection
   c. Heat retention
   d. Maintenance

8. Which of the following is a disadvantage for using glass as a covering material?

   a. Excellent light transmission
   b. Long life
   c. High cost
   d. Resistant to ultraviolet light deterioration

9. Acrylic is a rigid covering material also known as _________.

a. Plexiglass®
b. Lexan®
c. Tedlar®
d. PVC

10. Polycarbonate is a covering material that is _________.

a. Corrugated panels of glass fibers imbedded in plastic resins
b. Also known as Tedlar®
c. Profiled sheets with double-walled construction
d. Standard B grade, 26 ounce

11. Tedlar® is _________.

a. Also known as Lexan®
b. Not resistant to ultraviolet light deterioration
c. A polyester material which lasts 20 years
d. A polyvinyl fluoride film

12. Polyethylene is a covering material that is _________.

a. Expensive
b. Long lived
c. Seldom used
d. Easy to install

13. A moveable framework of glass, fiberglass, or other glazing materials is called a (an) _________.

a. Eave plate
b. Side ventilator
c. Sash
d. Transom sill

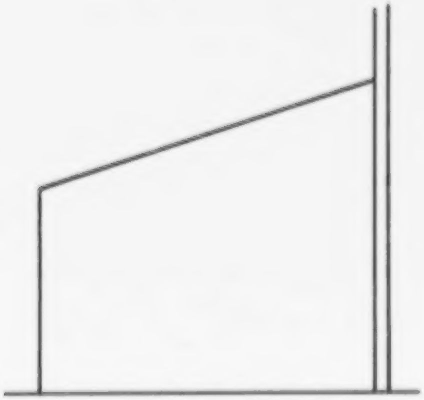
14. The hinged structure at the eave plate which closes on the transom sill is called the _________.

a. Strut
b. Side ventilator
c. Ridge
d. Purlin

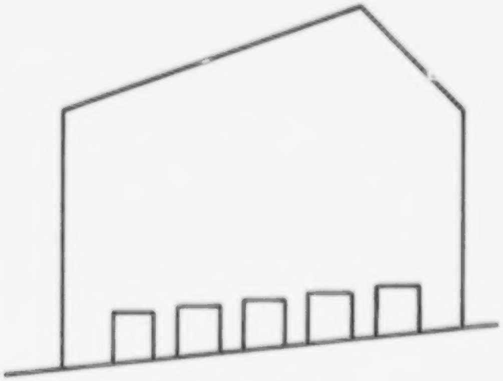
15. The lengthwise section of greenhouse between two vertical side posts or other structural members is called a _________.

a. Bay
b. Girt
c. Side ventilator
d. Wall sill

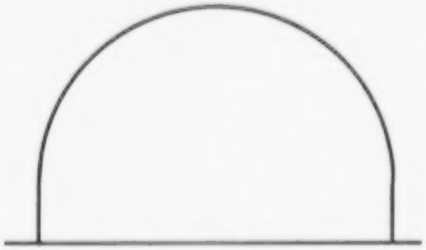
Styles of Greenhouses



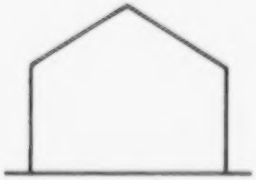
Lean-to



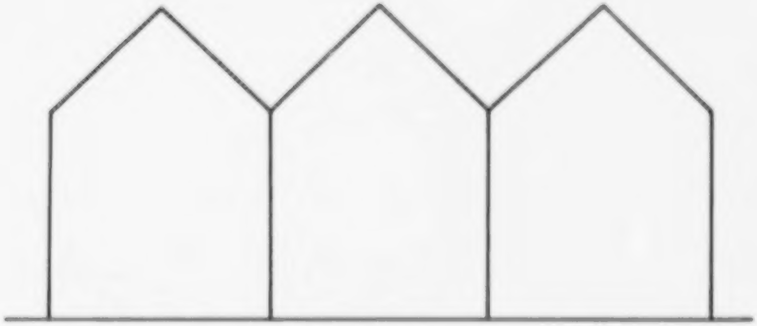
Uneven Span



Quonset



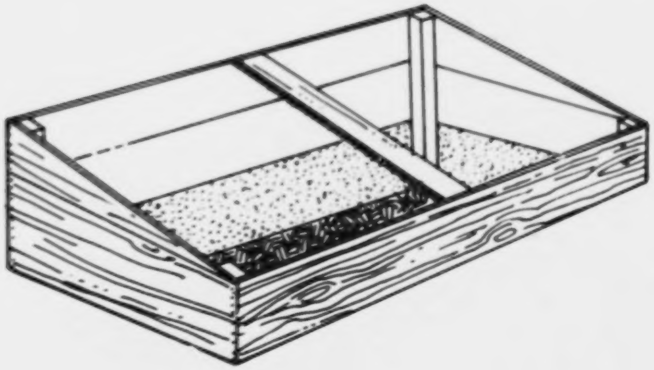
Dutch Type
(an even span type)

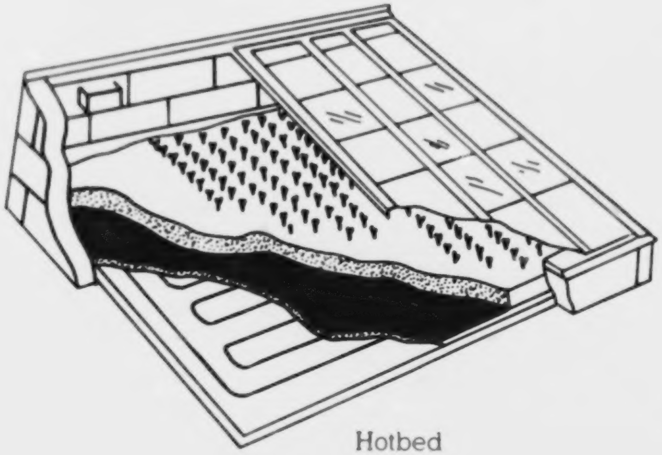


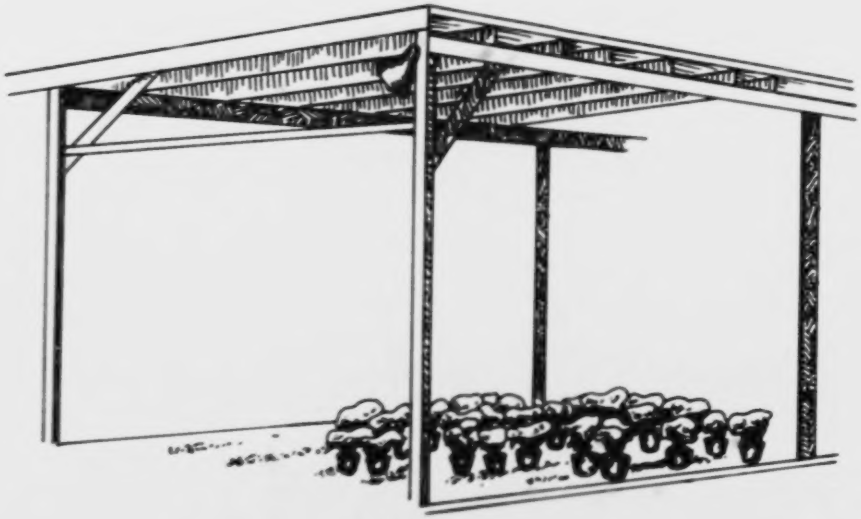
Ridge-and-Furrow

TM 4.2

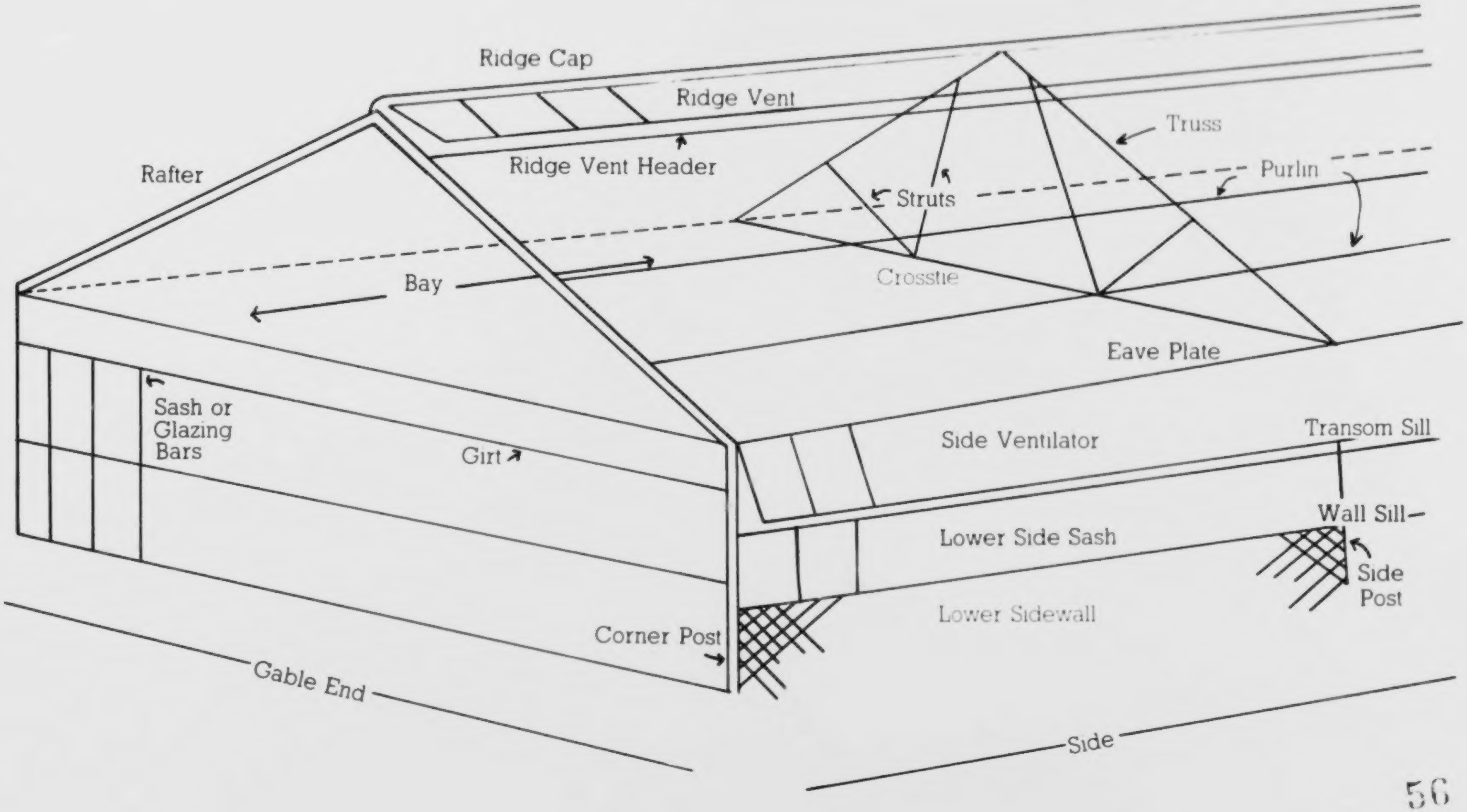
Other Related Structures


Coldframe


Hotbed


Lathhouse

Parts of a Greenhouse


Ridge Cap
Ridge Vent
Truss
Ridge Vent Header
Purlin
Rafter
Struts
Bay
Crosstie
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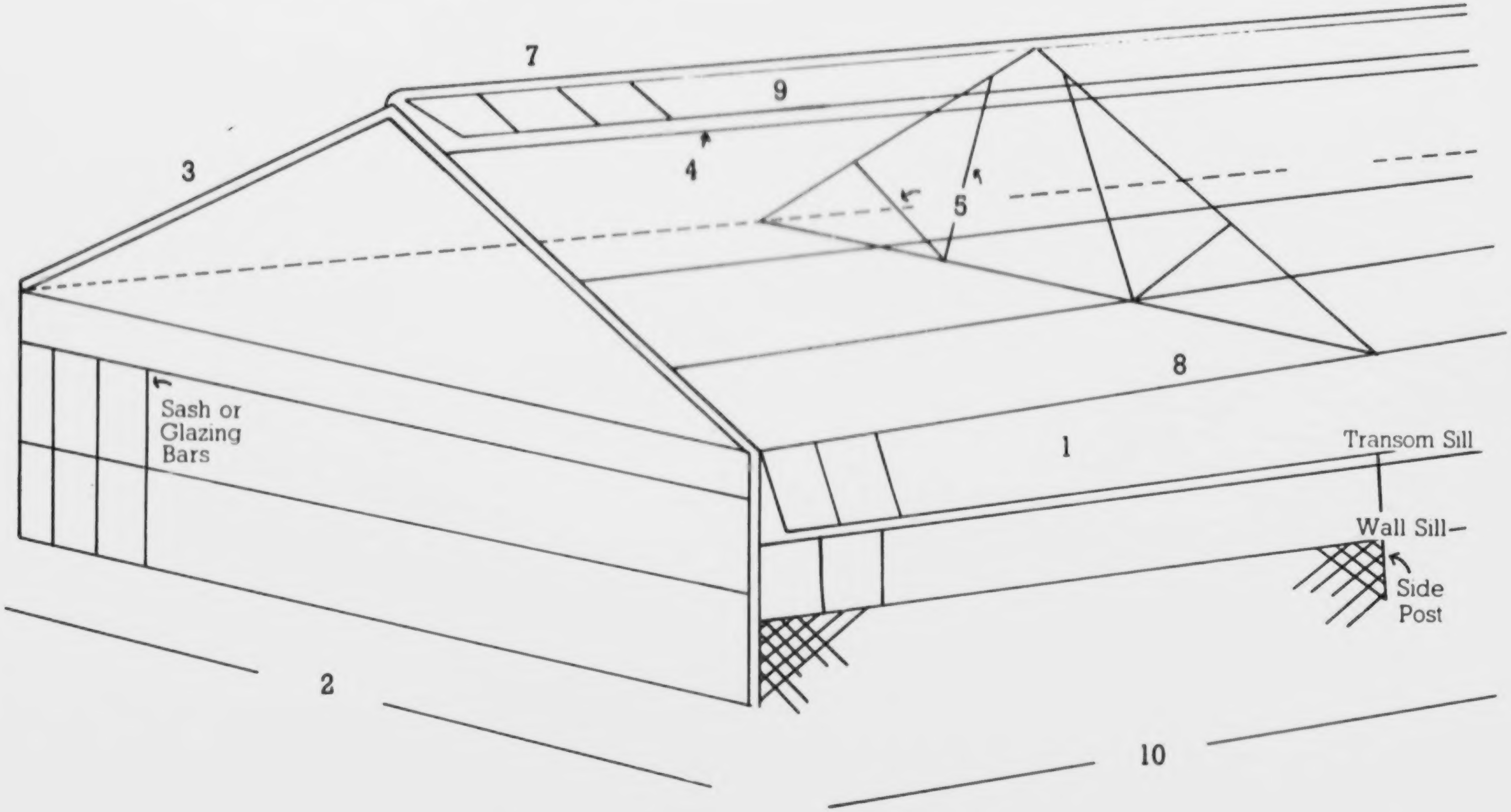
Sash or Glazing Bars
Girt
Side Ventilator
Transom Sill
Wall Sill
Lower Side Sash
Side Post
Lower Sidewall
Corner Post
Gable End
Side

56

55

Parts of a Greenhouse


7
9
3
4
5
Sash or Glazing Bars
8
1
Transom Sill
Wall Sill—
Side Post
2
10

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 5: Greenhouse Environmental Control

Objective: The student will be able to describe the operation of environmental controls and equipment found in a greenhouse such as ventilation, heating, cooling, air circulation, and irrigation.

Study Questions

1. **What are the purposes of ventilation?**
2. **What equipment is necessary for each type of ventilation?**
3. **What are the methods for heating a greenhouse?**
4. **What equipment is necessary for heating?**
5. **What equipment is necessary for each cooling method?**
6. **What are the reasons for air circulation?**
7. **What are the methods of air circulation?**
8. **What are the methods of irrigation?**
9. **What equipment is necessary for automatic irrigation?**
10. **What other equipment is found in a greenhouse?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Masters

    a) TM 5.1 Methods of Ventilation
    b) TM 5.2 Evaporative Cooling Pad System

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 5: Greenhouse Environmental Control

TEACHING PROCEDURES

A. Review

Review the previous lesson.

B. Motivation

A greenhouse worker needs to understand the environmental controls found in a greenhouse. The proper environment has a direct effect on the quality of plants produced. To produce high quality plants, it is important to understand how to manipulate the greenhouse environment by providing the proper ventilation, heating, cooling, air circulation, and irrigation.

C. Assignment

D. Supervised study

E. Discussion

1. Ask students to list reasons why ventilation systems are used in greenhouses.

   What are the purposes of ventilation?

   a) To reduce the temperature
   b) To introduce fresh air into the greenhouse
   c) To reduce relative humidity to control plant diseases

2. Have students list the three methods of ventilation and the equipment needed for each. Use TM 5.1.

   What equipment is necessary for each type of ventilation?

   a) Ridge and side ventilators - "chimney effect"
      1) Manual operating system components
         (a) Hand cranks, chain pulls, and levers may open the vents or be attached to gear-driven units.
         (b) Gear-driven unit may be connected to the vent.
            (1) Elbow arm
            (2) Rack-and-pinion device
      2) Power system - A thermostat can be connected to the power-driven system, making the ridge and side ventilator operation completely automatic.
   b) Forced-air fans
      1) Fans are used in late spring, summer, and early autumn to draw in fresh air.
      2) A thermostat connected to the exhaust fans automatically turns them on and off.
   c) Perforated convection tube heater/fan system
      1) Motorized louvers let in cold fresh air.
      2) Fans mix the heated air with air inside the greenhouse and distribute it through the convection tube.
      3) Convection tube runs the length of the greenhouse overhead and distributes air through the perforated openings.
      4) If dehumidification is desired, air is heated via unit heaters before being introduced into the convection tube.

3. Discuss with students the heat sources and factors to consider when selecting a fuel to heat a greenhouse. Point out that although the sun does provide some heat for a greenhouse, it cannot be relied upon to deliver a constant source of heat.

What are the methods for heating a greenhouse?

a) Heating systems
    1) Boilers
        (a) Used to heat larger greenhouse ranges
        (b) During the combustion of fossil fuels, steam is formed or water is heated.
        (c) Often use radiant piping to distribute heat from steam or hot water
    2) Unit heaters
        (a) Used in smaller greenhouses
        (b) Use fossil fuel to generate hot air
    3) Radiant or infrared heaters
        (a) Infrared radiation heats objects.
        (b) Air is not heated.
b) Emergency generating and/or heating method - used only when the regular heating source fails

4. Discuss with students the equipment necessary for heating a greenhouse.

What equipment is necessary for heating?

a) Boilers - steel or cast iron
    1) Steam heating systems
        (a) Several fuels can be used.
            (1) Coal
            (2) No. 2 oil
            (3) Kerosene
            (4) LP gas
            (5) Natural gas
        (b) Steam is used in large greenhouses having 15,000 sq. ft. or more.
        (c) This system produces steam at 212°F (100°C).
        (d) Steam mains have 1 1/2" distribution pipes.
        (e) One linear foot of steam pipe distributes 180 Btu/hour.
        (f) Pipes may be located under benches, overhead, or around the perimeter of the greenhouse.
    2) Hot water heating systems
        (a) Several fuels can be used.
            (1) Coal
            (2) No. 2 oil
            (3) Kerosene
            (4) LP gas
            (5) Natural gas
        (b) Hot water is often used for smaller greenhouse ranges but may be used for larger ones also.
        (c) Water is heated to 180°F. (82.2°C)
        (d) This system provides a more constant heat than steam.
        (e) Hot water mains have 2" distribution pipes.
        (f) One linear foot of hot water pipe distributes 160 Btu/hour.
        (g) Pipes may be located under benches, overhead, or around the perimeter of the greenhouse.
b) Unit heaters
    1) Can operate independently
    2) Can distribute energy from a steam or hot water boiler system
    3) Distribute heat by fans or convection tubes
    4) Burn a variety of fuels
        (a) LP or natural gas is used by 90 percent of unit heaters.

      - (b) No. 2 oil is used by nearly all the rest.
    - 5) Generate hot air by the combustion of fossil fuels
      - (a) Oxygen is consumed.
      - (b) Toxic gases may be released.
      - (c) Provide proper fresh air intake; One square inch of outside opening should be provided near the heater for every 2,000 Btu capacity.
  - c) Radiant or infrared heaters
    - 1) These heaters are placed overhead running the length of the greenhouse.
    - 2) Heaters are spaced 20 to 30 feet apart.
    - 3) Vacuum combustion produces high temperatures in 2-inch pipes and radiant energy is deflected down.
    - 4) Radiant heaters are fueled by LP gas, natural gas, or electricity.
    - 5) Radiant or infrared heaters are 93 percent efficient.
  - d) Emergency generators and/or heaters
    - 1) Used only when the regular heating source fails
    - 2) Standby electrical generator to furnish emergency power
    - 3) Back-up heater - portable gas burners
      - (a) Maintain emergency heaters in good working order
      - (b) Provide an adequate emergency fuel supply

5. Discuss the equipment needed for each cooling method used in a greenhouse. Use TM 5.2 to illustrate the evaporative cooling pad system.

   What equipment is necessary for each cooling method?

   - a) Ventilation - "chimney effect"
     - 1) Ridge vents
     - 2) Side vents
   - b) Forced-air system
     - 1) Inlet shutter
     - 2) Fans
   - c) Evaporative cooling system
     - 1) Wet pads are located either inside or outside the side vent on the prevailing wind side of the greenhouse.
       - (a) Excelsior - lasts one year
       - (b) Cross-fluted cellulose material
         - (1) Looks like corrugated cardboard
         - (2) May last ten years
       - (c) Aluminum - need not be replaced but must be kept clean
       - (d) Spun plastic
     - 2) Fans are placed opposite the cooling pads.
   - d) Shading - whitewash, commercial shading compound, or shade cloth applied to covering material in late spring

6. Discuss with the students the reasons why it is important to circulate air in the greenhouse.

   What are the reasons for air circulation?

   - a) Improves heat distribution and creates a more uniform environment
   - b) Reduces the relative humidity in conjunction with other equipment, which reduces plant diseases
   - c) Increases the rate of carbon dioxide replenishment around the leaf surface

7. Discuss with the students the methods and equipment necessary for air circulation.

   What are the methods of air circulation?

   - a) Turbulator fan system
     - 1) Overhead installation

    2) Air moved down towards plants
    3) Large quantities of air moved at a very slow velocity
    4) In continuous operation except when cooling
  b) Perforated convection tube heater/fan system
    1) Runs the length of the greenhouse overhead
    2) Distributes air through perforated openings
    3) Fan in continuous operation
    4) Additional uses
      (a) Ventilation
      (b) Heat distribution
      (c) Reduces relative humidity
      (d) Minimal cooling in winter

8. Have students list the methods of irrigation.

What are the methods of irrigation?

  a) Manual
    1) Most common method
    2) Most expensive to operate
    3) Conscientious person required
    4) Easy adaptability of moisture needs of various crops
  b) Automatic
    1) Types
      (a) Overhead
      (b) Bench level
      (c) Drip
      (d) Subirrigation
    2) Benefits
      (a) More uniformly watered plants
      (b) Savings of labor costs
      (c) Long lasting systems - 3 to 10 years

9. Discuss with students the equipment necessary for irrigation.

What equipment is necessary for automatic irrigation?

  a) Automatic watering systems
    1) Overhead watering systems
      (a) Hanging sprayers
        (1) Nozzles are spaced five feet apart.
        (2) Nozzles have a 360° discharge.
        (3) Water is applied by heavy mist in a circular spray pattern.
      (b) Spray-stakes
        (1) Nozzles are supported on stiff stakes set into the bench.
        (2) Stake heights are 10 to 36 inches.
        (4) Water main runs down center of bench.
        (3) Nozzles are pointed up and have spray patterns of 180° and 360°.
    2) Bench level irrigation systems
      (a) Center-of-bed discharge system
        (1) Water main runs down center of bench.
        (2) Nozzles are set two inches above the soil and three feet apart.
        (3) Nozzles have a flat spray pattern.
      (b) Perimeter discharge system
        (1) Water main is placed around the perimeter of the bench.
        (2) Nozzles have a 180° spray pattern.
        (3) Nozzles are spaced two to three feet apart.
    3) Drip systems
      (a) Spaghetti tube system

        - (1) A narrow diameter tube runs from the water main to each pot.
        - (2) Tube ends are weighted to keep them from falling out.
        - (3) A valve is used at each bench to manually or automatically control the water flow.
      - (b) Water loops
        - (1) Water loops are perforated circular loops of plastic.
        - (2) Water loops are placed around the stem of the plant.
        - (3) Various diameters are available.
      - (c) Ooze systems
        - (1) 3/4-inch porou plastic hose
        - (2) Water oozes out through the length of hose.
        - (3) Ooze hoses are spaced 8 to 12 inches apart and run the length of the bench.
      - (d) Drip hose
        - (1) System consists of 1-inch twin-walled flexible plastic hoses with holes every 12 inches.
        - (2) Water drips out the hose.
        - (3) Drip hoses are spaced 8 to 12 inches apart running the length of the bench.
    - 4) Subirrigation systems
      - (a) Capillary mats
        - (1) Capillary mats are ideal for small pots.
        - (2) Capillary mats are ideal for plants like African violets, whose foliage should not get wet.
        - (3) Black plastic is placed on a level bench.
        - (4) Cover with fine sand or a capillary mat.
        - (5) The ooze or drip system is used to supply water.
        - (6) Place the plant on mat.
        - (7) Water the plant from top to establish the capillary action.
      - (b) Embedded ooze system
        - (1) Porous plastic foam hose is buried in the soil.
        - (2) Water seeps through the pores.
        - (3) Hoses are spaced two feet apart.
      - (c) Ebb and flow
        - (1) The waterproof bench forms a reservoir.
        - (2) Pots are placed in the bench.
        - (3) The bench is flooded several inches deep.
        - (4) Excess water is allowed to drain and is recycled later.
  - b) Automatic watering controls
    - 1) Flowage
      - (a) A small amount of water flowing into the irrigation system is diverted into a container.
      - (b) When a predetermined quantity or weight is in the container, the water supply shuts off.
    - 2) Pilot pot
      - (a) A sensor is placed in the base of a pilot pot.
      - (b) The sensor shuts the water off when the soil mass becomes heavy enough.
    - 3) Timer
      - (a) A timer or a series of timers are used.
      - (b) Irrigation systems turn on and off at predetermined intervals, usually a certain number of minutes.

10. Ask the students what other environmental equipment is found in a greenhouse. Discuss why and how each of these additional equipment is used.

    What other equipment is found in a greenhouse?

    - a) Propagation bed
      - 1) Enclosed frame can be covered with glass or plastic.

        2) It contains propagation media and an automatic mist system, as well as an under-media heat source.
        3) Mist system is controlled to produce a fine mist periodically during the day.
        4) There is a danger of bacterial and fungal diseases; propagation beds must be thoroughly cleaned periodically.

    b) Carbon dioxide generator
        1) The use of a carbon dioxide generator results in an increased rate of growth and development of plants.
        2) The carbon dioxide generator is needed only during daylight.
        3) Most common type of CO_2 generator is a burner that burns gas or oil.
        4) The generator increases the CO_2 concentration in the atmosphere from the existing 300 ppm to 1,000 ppm or more.

    c) Fertilizer proportioners
        1) Liquid fertilizer concentrate is added to the water as it is used to irrigate the plants.
        2) There are two types of proportioners.
            (a) Injector - automatically injects a uniform volume of liquid fertilizer concentrate into an automatic watering system
            (b) Siphon - creates a pressure difference allowing variable amounts of liquid fertilizer concentrate into the irrigation water depending on the rate of water flow and pressure through a hose

    d) Photoperiodic control
        1) Extending day length (lighting)
            (a) Incandescent light bulbs
            (b) Minimum of 10 fc of light at plant tops
            (c) Lighting methods
                (1) Extending the day
                (2) Continuous lighting in the middle of the night
                (3) Cyclic lighting in the middle of the night
        2) Decreasing the day length (black cloth)
            (a) Black cloth is used to exclude all light.
            (b) Black cloth should be applied from 5 p.m. to 8 a.m.
            (c) Frames are used to keep the black cloth above the plants.
            (d) Black cloth is manually or automatically pulled over plants.

    e) Heat failure alarm
        1) Warns when the heating source fails in the greenhouse
        2) Also warns when overheating occurs
        3) May be an auditory bell, a flashing light, or a telephone automatic dialing warning system

F. Other activities

1. Tour a greenhouse and point out the environmental controls and equipment. Demonstrate how the equipment operates.

2. Take students on a field trip to compare local greenhouses. Have students fill out an assignment sheet noting such things as greenhouse type, covering material, superstructure, heating, cooling, and ventilation.

G. Conclusion

A knowledge of the greenhouse environment is necessary in order to grow plants most effectively. Environmental controls (i.e., ventilation, heating, cooling, irrigation, and air circulation) must be carefully manipulated to achieve optimal plant growth.

H. Competency

Describe the operation of environmental controls and equipment found in a greenhouse.

I. Answers to Evaluation

1. b
2. c
3. d
4. c
5. d
6. a
7. d
8. a
9. c
10. c
11. c
12. d
13. a
14. c
15. b

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Name ___________________

Lesson 5: Greenhouse Environmental Control

Date ___________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Ventilation is used in a greenhouse to _________.

   a. Increase the temperature
   b. Decrease the temperature
   c. Reduce fresh air entering the greenhouse
   d. Increase the relative humidity

2. The three methods used to ventilate a greenhouse are _________.

   a. Turbulator fans, forced-air systems, and convection tubes
   b. Shading, roof and side vents, and forced-air systems
   c. Ridge and side vents, forced-air systems, and convection tubes
   d. Ridge and side vents, forced-air systems, and turbulator fans

3. Which of the following is not a fossil fuel used in greenhouse heating systems?

   a. Oil
   b. Coal
   c. Gas
   d. Sun

4. Steam heating systems _________.

   a. Are usually used for smaller greenhouses
   b. Produce steam at 180°F
   c. Distribute 180 Btu/hour/one linear foot of pipe
   d. Consist of 2" distribution pipes

5. Pipes used to distribute the heat produced by a boiler in a greenhouse may be located _______________.

   a. Along the sidewalls
   b. Under the benches
   c. Overhead
   d. All of the above

6. Unit heaters that use combustible fuels _________.

   a. Must be provided with fresh air intake
   b. Consume carbon monoxide
   c. Release oxygen
   d. Do not need to be vented

7. In radiant heaters, _________.

   a. Heat is distributed at the rate of 160 Btu/hour/one linear foot of pipe
   b. Heat is distributed at the rate of 180 Btu/hour/one linear foot of pipe
   c. Both condensation and excess humidity are problems
   d. Vacuum combustion produces high temperature air distributed through two-inch pipes

8. In relation to the wet pads, the location of the exhaust fans in a greenhouse cooling system is ___________.

a. Opposite
b. Adjacent
c. At right angles
d. Either above or below

9. The most common method of irrigating greenhouse crops is _________.

a. Automatic
b. Spaghetti tube system
c. Manual
d. Spray-stakes

10. Convection tubes would not be used for _________.

a. Air circulation
b. Cooling
c. Irrigation
d. Ventilation

11. A carbon dioxide generator _________.

a. Is used to reduce the CO_2 concentration
b. Results in limiting the rate of growth of plants
c. Is needed only during daylight
d. Runs continuously

12. To extend the day length to obtain photoperiodic control, _________.

a. Use incandescent light bulbs that produce 10 foot candles of light
b. Provide continuous lighting in the middle of the night
c. Provide 6 minutes of light every 30 minutes from 10 p.m. to 2 a.m.
d. Any of the above

13. The use of black cloth _________.

a. Excludes all light from 5 p.m. to 8 a.m.
b. Can only be done automatically
c. Increases the day length
d. Allows for the black cloth to rest gently on the plants

14. Motorized louvers and unit heaters are part of the equipment needed to operate which type of ventilation system?

a. Ridge and side ventilation
b. Forced air system
c. Convection tube system
d. Evaporative cooling system

15. Which of the following irrigation systems is the most expensive to operate?

a. Overhead system
b. Hose
c. Water loops
d. Capillary mats

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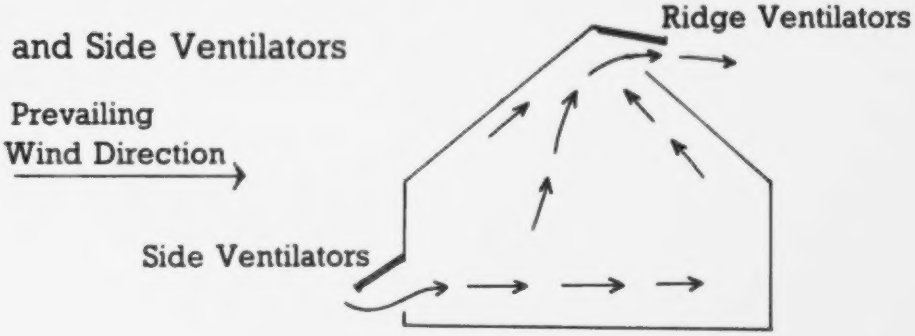
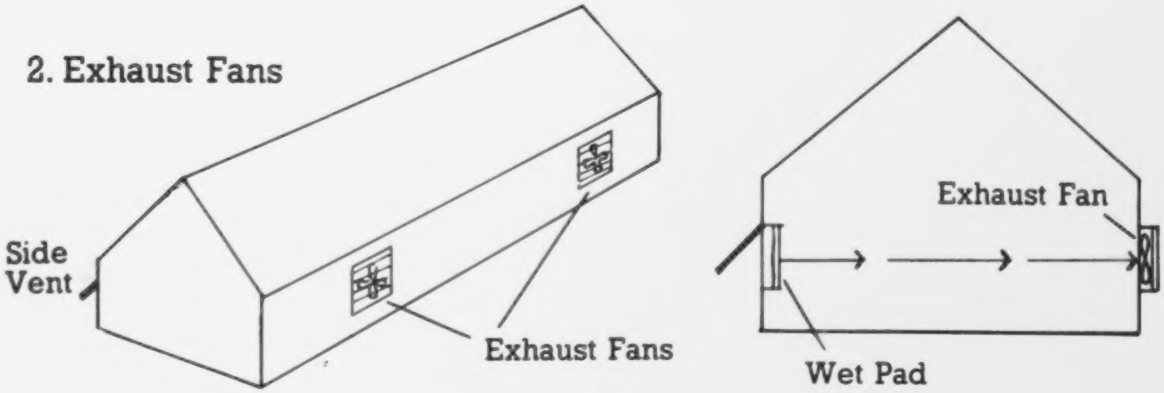
Methods of Ventilation

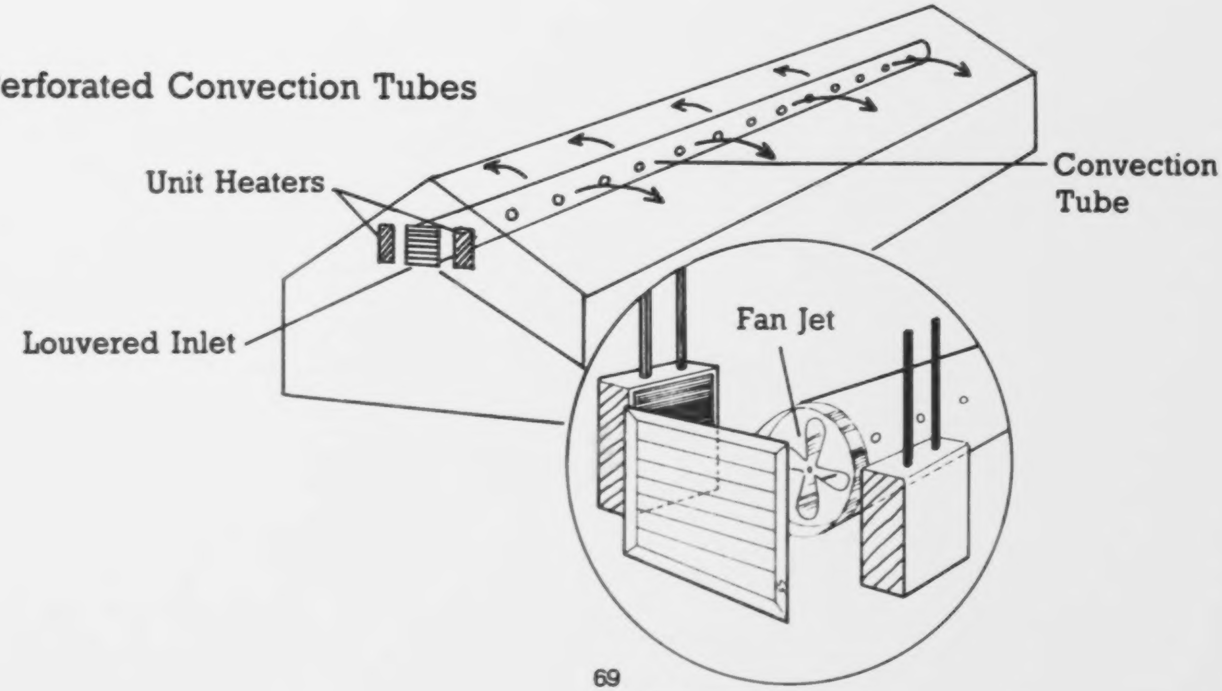
1. Ridge and Side Ventilators


Ridge Ventilators
Prevailing
Wind Direction
Side Ventilators

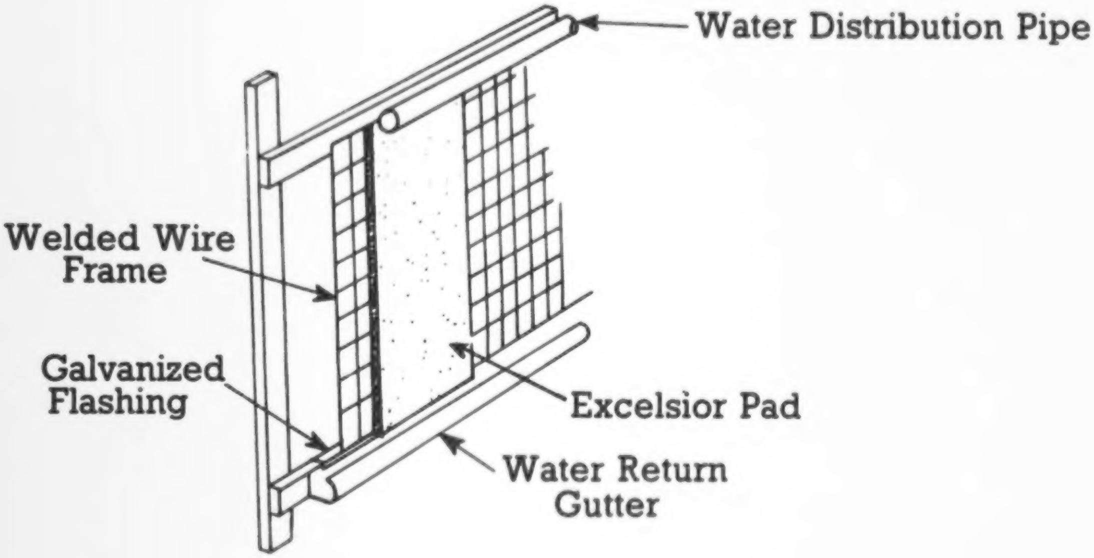
2. Exhaust Fans


Side
Vent
Exhaust Fans
Exhaust Fan
Wet Pad

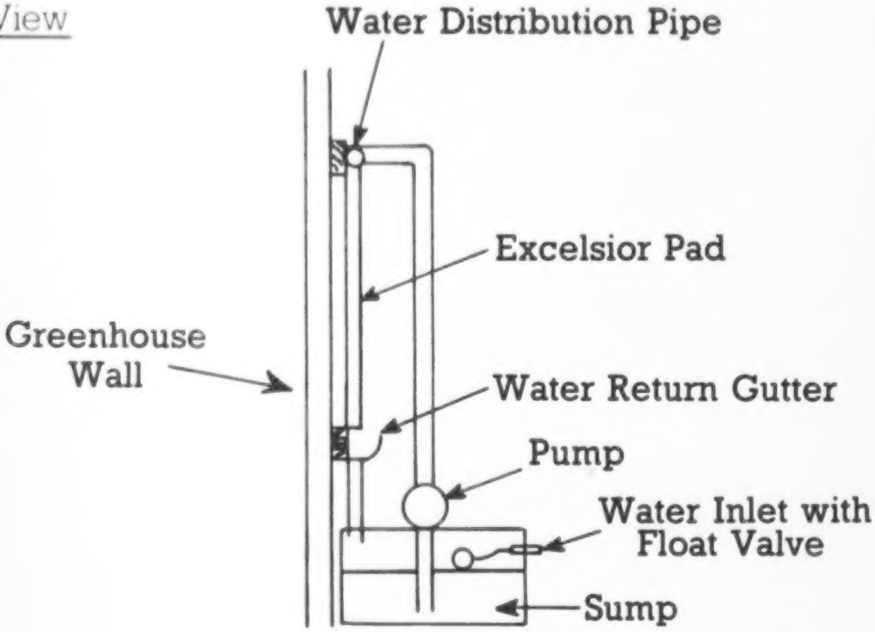
3. Perforated Convection Tubes


Unit Heaters
Convection
Tube
Louvered Inlet
Fan Jet

Evaporative Cooling Pad System


Water Distribution Pipe
Welded Wire Frame
Galvanized Flashing
Excelsior Pad
Water Return Gutter

Front View


Water Distribution Pipe
Excelsior Pad
Greenhouse Wall
Water Return Gutter
Pump
Water Inlet with Float Valve
Sump

Side View

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 6: Interior Layout

Objective: The student will be able to analyze suitable interior layouts, according to greenhouse purpose.

Study Questions

1. **How does interior layout design differ between wholesale and retail greenhouses?**
2. **What is the importance of raised benches in the greenhouse?**
3. **What are the different types of benching layout designs?**
4. **What are bench and walkway dimensions in a greenhouse?**
5. **What are the characteristics of the bench construction materials used in a greenhouse?**
6. **What are the characteristics of the different walkway materials?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Master
    a) TM 6.1: Interior Layouts of Greenhouses

Lesson 6: Interior Layout

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

In order to produce the maximum number of plants in the minimum amount of space, it is important to have an understanding about interior layouts of greenhouses. The basic interior layouts of greenhouses will be discussed along with the materials used for benches and walkways. The differences between interior layouts for wholesale and retail greenhouses will be covered.

C. Assignment

D. Supervised study

E. Discussion

1. Have students discuss the difference between the interior layouts of wholesale and retail greenhouses.

How does the interior layout differ between wholesale and retail greenhouses?

a) Wholesale greenhouses
    1) Maximum usage of space for crop production is emphasized.
    2) Overhead space is often used for hanging baskets.
    3) Benches are placed closer together.
    4) Plants are more crowded on the benches.
    5) Benches tend to be higher (about 30" tall) than in a retail operation.
    6) Usually the facilities are less convenient for workers than in the retail greenhouse.
    7) Aisles or walkways are narrower.
    8) Benches are wider.
    9) The environment may not be aesthetically beautiful.

b) Retail greenhouses
    1) The stimulation of customer purchases through a pleasing environment is emphasized.
    2) Fewer baskets are hung overhead for better display.
    3) Benches are placed further apart and more conveniently arranged.
        (a) Peninsular benching
        (b) Lower benches - 24 to 30 inches high so plants are within easy reach
    4) Plants are spaced further apart on benches.
        (a) Breakage and damage to plants is reduced.
        (b) Customer may view plants better.
    5) Wider aisles or walkways are finished in gravel or concrete.
    6) The greenhouse is well lit with artificial light.
    7) Plants and supplies are within easy reach of customer.
    8) The environment is more convenient for workers.
    9) The environment is aesthetically beautiful; appearance is important.

2. Ask students to discuss the importance of greenhouse benches.

What is the importance of raised benches in the greenhouse?

a) Improve air circulation
b) Increase drainage away from container-grown plants
c) Isolate plants from diseases and insects
d) Reduce energy costs
e) Enhance worker efficiency

3. Discuss with students the different types of benching layout designs. Point out possible advantages and disadvantages of each. Use TM 6.1.

What are the different types of benching layout designs?

a) Lengthwise or longitudinal
  1) Used for cut flower production
  2) May reduce worker efficiency
  3) Support provided for under bench heating and water lines
b) Crosswise or island
  1) Used for container-grown plants, bedding plants, education, and research
  2) Increased worker efficiency
  3) Efficient use of space
c) Peninsular
  1) Used for container-grown plants and bedding plants (young starter plants, most flowering annuals, or any others for planting in home garden beds)
  2) Modification of crosswise benching
  3) Wide center walkway
  4) More growing area provided than crosswise benching
  5) Preferred for retail and wholesale greenhouse operations
d) Moveable
  1) Used for container-grown plants having few cultural care requirements
  2) Maximum efficiency of greenhouse space
  3) Only one aisle

4. Ask students the bench and walkway dimensions in a greenhouse.

What are bench and walkway dimensions in a greenhouse?

a) Bench dimensions
  1) Height 24 to 30 inches (generally higher for wholesale and lower for retail container-grown)
  2) Width varies
    (a) Maximum of 5 to 6 feet for container-grown plants
    (b) 3 to 4 feet for cut flowers
    (c) Up to 6 1/2 feet for moveable benches
b) Width of walkway or aisle dimensions
  1) 18 inches for cut flower benches
  2) 24 inches for container-grown plants
  3) 48 inches center walkway

5. List the basic types of benching materials used and have students list the advantages and disadvantages of each.

What are the characteristics of the bench construction materials used in a greenhouse?

a) Wood
  1) General characteristics
    (a) Used for ground beds and raised benches
    (b) Relatively inexpensive cost for most woods
    (c) Lightweight; adaptable to moveable benches

        - (d) Readily available
        - (e) Easy to construct
        - (f) Short life, unless treated
        - (g) Water absorption
        - (h) Only pots three inches or larger used with wood lath bench material
    - 2) Types of woods recommended for the greenhouse environment
        - (a) Redwood does not require a wood preservative.
            - (1) Corrosive to iron and steel
            - (2) Second most expensive bench material
            - (3) Redwood lath in woven wire
        - (b) Cypress does not require a wood preservative.
        - (c) Cedar does not require a wood preservative.
        - (d) All other woods used in the greenhouse must be treated with a wood preservative to enhance longevity.
            - (1) Chrome copper arsenate (CCA)
            - (2) Copper naphthanate
            - (3) Latex paint
            - (4) Zinc naphthanate
- b) Concrete
    - 1) Used for ground beds and raised benches
    - 2) Used for cut flowers
    - 3) Most durable
    - 4) Second or third most expensive, depending on installation costs
    - 5) Stands up to steam sterilization
    - 6) Not adaptable to moveable benches
- c) Expanded metal fabric
    - 1) Used for raised benches
    - 2) Used for container-grown plants
    - 3) Pre-fabricated panels of varying sizes
    - 4) Adaptable to moveable benches
    - 5) Maximum air circulation
    - 6) No maintenance
    - 7) Most expensive
    - 8) Rusts
    - 9) Rough edges if not finished
- d) Wire mesh
    - 1) Used for raised benches
    - 2) Needs a frame of wood or metal for reinforcement
    - 3) Used for container-grown plants
    - 4) Least expensive
    - 5) Maximum air circulation
    - 6) Lightweight; adaptable to moveable benches
    - 7) Rusts
    - 8) Easily damaged
    - 9) Sags with weight of containers
- e) Plastic
    - 1) Used for raised benches
    - 2) Used for container-grown plants
    - 3) Available in only two sizes
    - 4) Lightweight; adaptable to moveable benches
    - 5) Durable
    - 6) Easy to clean
    - 7) Non-absorbent to water
    - 8) Third most expensive

6. Have students list the most common types of walkway materials and discuss characteristics of each.

What are the characteristics of the different walkway materials?

a) Gravel
    1) Least expensive
    2) No other drainage needed
    3) Rough surface
b) Concrete
    1) Most common
    2) Most expensive
    3) Standard concrete
        (a) Rough finish
        (b) Smooth finish - may be slick when wet
    4) Porous concrete - allows water to pass through
c) Asphalt
    1) Smooth surface
    2) Less expensive than concrete
    3) Must be resealed annually
    4) May be slick when wet

F. Other activities

Tour a wholesale greenhouse and retail greenhouse. Have students measure walkways and benches. Have students determine the square footage of bench space for both greenhouses.

G. Conclusion

The interior design of a greenhouse (i.e., bench and aisle walkway layout, dimensions, and choice of construction materials) is determined by the purpose of the facility--wholesale or retail--and the crops grown.

H. Competency

Analyze suitable interior layouts according to greenhouse purpose.

I. Answers to Evaluation

1. c
2. d
3. a
4. b
5. b
6. b
7. c
8. a
9. c
10. a
11. b
12. a
13. b
14. b
15. a
16. a
17. b

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ______________

Lesson 6: Interior Layout Date ______________

EVALUATION

Match the basic interior layouts of greenhouses with their definitions.

____ 1. lengthwise benching

____ 2. crosswise benching

____ 3. peninsular benching

____ 4. moveable benching

a. modification of crosswise benching, provides more growing area

b. maximum efficiency of greenhouse space, uses only one aisle

c. used for cut flower production, worker efficiency is reduced

d. used for container-grown crops, more efficient for workers

Circle the letter that corresponds to the best answer.

5. Select the type of wood that is least adapted for use in the greenhouse environment.

   a. Cypress
   b. Pine
   c. Redwood
   d. Cedar

6. The most durable bench construction material is ________.

   a. Wood
   b. Concrete
   c. Wire mesh
   d. Expanded metal

7. Which of the following wood preservatives is recommended for greenhouse use?

   a. Pentachlorophenol
   b. Creosote
   c. Latex paint
   d. a and c

8. Select the construction material used for both ground beds and raised benches.

   a. Wood
   b. Expanded metal
   c. Wire mesh
   d. Plastic

9. What type of bench construction material is lightweight, easy to move, and sags with weight?

   a. Wood
   b. Expanded metal
   c. Wire mesh
   d. Plastic

10. A walkway made of rough textured concrete ________ .

a. Is not slick when wet
b. Is not expensive
c. Must be resurfaced yearly
d. Has good drainage

Match the purpose of the greenhouse with the correct interior layout conditions.

____ 11. well-lit with artificial lighting

____ 12. benches closer together

____ 13. wider walkways

____ 14. lower benches

____ 15. narrower aisles

____ 16. maximum usage of growing space

____ 17. plants and supplies within easy reach

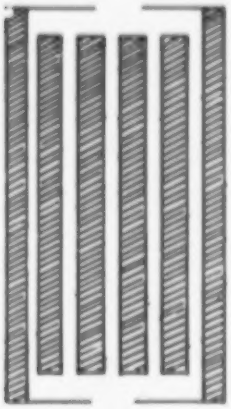
a. wholesale greenhouse

b. retail greenhouse

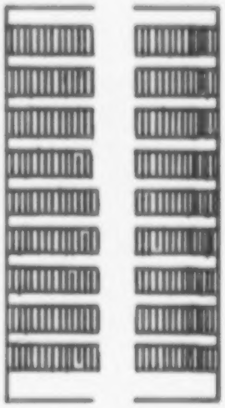
TM 6.1

Interior Layouts of Greenhouses

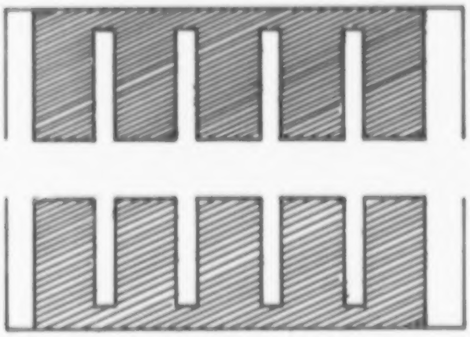
Lengthwise Benching
(Longitudinal)



Crosswise Benching
(Island)



Peninsular Benching



UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 7: Energy Conservation

Objective: The student will be able to describe different modifications and procedures used to conserve energy in greenhouses.

Study Questions

1. **Why is energy conservation important in the greenhouse?**
2. **How do greenhouse orientation, geographic location, and climate affect energy conservation?**
3. **How can windbreaks be used to conserve energy?**
4. **What greenhouse modifications and procedures conserve energy?**
5. **What are some cultural procedures that can be used to conserve energy?**

Reference

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 7: Energy Conservation

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

Since the cost of heating is the second highest overhead cost, it is important to understand the different modifications and procedures for conserving energy in greenhouses. By keeping the cost of heating down, the savings can be reflected in the net profit.

C. Assignment

D. Supervised study

E. Discussion

1. Ask students to discuss why energy conservation is important in the greenhouse.

   Why is energy conservation important in the greenhouse?

   The increasing costs of fossil fuels needed to heat a greenhouse result in higher production costs.

2. Ask students to discuss how greenhouse orientation, based on geographic location and climate, affects energy conservation.

   How do greenhouse orientation, geographic location, and climate affect energy conservation?

   a) Orient the long axis of the greenhouse north-south when located south of the Mason-Dixon line (38th parallel), and east-west when located north of the line in order to intercept the greatest amount of year-around sunshine.
   b) The structure should be built in an area protected from harsh prevailing winds, especially in areas of low winter temperatures.
   c) The smallest cross section of a greenhouse should face the prevailing winds.
   d) Some climatic conditions that must be considered when orienting a greenhouse include average annual temperature, percentage of annual sunlight, wind velocity and direction, and precipitation.

3. Ask students to list some naturally occurring windbreaks. Then discuss how windbreaks conserve energy.

   How can windbreaks be used to conserve energy?

   a) Windbreaks provide a protected location for the greenhouse.
   b) When constructed properly, windbreaks can provide five to ten percent fuel savings.
      1) Windbreaks should never cast a shadow.
      2) Windbreaks on the east, west, or south side should be a distance of 2 1/2 times the height of the windbreak away from the greenhouse.
   c) Windbreaks should be porous to reduce wind velocity and energy consumption.

4. Ask student to discuss what modifications and procedures can be used in either a new or existing greenhouse to help conserve energy.

What greenhouse modifications and procedures conserve energy?

- a) Install double-layer polyethylene by itself.
  - 1) An inflated airspace of 5/8 to 4 inches between the layers of polyethylene retains 33 to 40 percent more heat than glass.
  - 2) An insulating airspace is created.
  - 3) Four-inch squirrel cage blowers run continuously to keep the air space inflated.
  - 4) Polyethylene will need replacing every two to three years.
  - 5) Light intensity is reduced by 18 percent.
- b) Install a double layer of polyethylene over existing cover of glass or fiberglass.
  - 1) The polyethylene safeguards against an infiltration through existing cover.
  - 2) An insulating airspace is created.
  - 3) Four-inch squirrel cage blowers run continuously to keep the air space inflated.
  - 4) Fuel savings of up to 57 percent may result.
  - 5) Polyethylene will need replacing every two to three years.
  - 6) Light intensity is reduced by 18 percent.
- c) Replace covering with laminated glazing material.
  - 1) 40 to 50 percent fuel savings
  - 2) Double-skinned material such as acrylic or polycarbonate
  - 3) Expensive
- d) Lap sealing a glass greenhouses.
  - 1) Process of injecting clear sealant between glass panes
  - 2) One-time process to last the life of the greenhouse
  - 3) Fuel savings of five to 40 percent, depending upon the original tightness of the glass
- e) Add thermal blankets.
  - 1) Curtain of polyethylene, Mylar®, or aluminized fabric
  - 2) Curtain drawn over the growing area and around the inside perimeter of the greenhouse at night
  - 3) Retracted each morning
  - 4) Reduce amount of space heated
  - 5) Radiant heat reflected toward the plants
  - 6) Conductive heat loss reduced by forming an insulated barrier above the plants
  - 7) Fuel consumption reduced by 40 to 65 percent after installation
  - 8) Overhead heating systems modified to distribute heat under the thermal blanket
  - 9) Necessary to protect water pipes above thermal blanket from freezing
  - 10) Avoid using the thermal blanket during snow or ice conditions especially at night; accumulation of snow or ice may cause the roof to collapse.
  - 11) Can be used as black cloth for photoperiod control
- f) Insulate sidewalls and foundations.
  - 1) Three to six percent savings in fuel after installation
  - 2) Insulation materials
    - (a) Rigid white Styrofoam® sheeting
      - (1) Lightweight
      - (2) Inexpensive
      - (3) Reflects light
    - (b) White Microfoam®
      - (1) Closed-cell polyethylene foam
      - (2) Inexpensive
      - (3) Reflects light
      - (4) Deteriorates quickly
      - (5) Flexible
      - (6) Easily cut for custom shaping around vents
    - (c) Bubble-pack type material
      - (1) Two layers of clear polyethylene bonded together with air bubbles in between

(2) Easily applied to the existing covering
(3) Reduces light transmission by eight percent
(d) Blueboard polystyrene for underground insulation
g) Completely insulate the north-facing end wall.
1) Especially beneficial in cold climates
2) Inexpensive
3) White Styrofoam® or Microfoam® to reflect light
4) Protects from harsh north winds of winter
h) Provide proper maintenance of the greenhouse covering and heating equipment.
1) Heat savings of three to ten percent by replacing broken glass, sealing cracks, and covering vents
2) Care of heat equipment
(a) Cleaned annually
(b) Inspected annually
(c) Adjusted for maximum fuel efficiency on a regular basis
3) Adequate fresh air intake for complete combustion for unit heaters that burn fossil fuels
i) Convert to radiant heaters.
1) Fuel savings of 30 percent or more
2) Can be combined with thermal blankets if the ridge is more than 12 feet high
3) Thermal blankets running from eave to ridge
j) Install air circulation fans.
1) Return warm air from attic downward to plants
2) Save heating costs

5. Ask students what cultural procedures, or practices used when growing greenhouse crops, will conserve energy.

What are some cultural procedures that can be used to conserve energy?

a) Lower night temperatures
1) Usually increase production time
2) Use of warm water promotes growth of crops in a cool greenhouse
3) Plants that require cooler night temperatures during the winter well-suited for this practice
(a) Cineraria
(b) Calceolaria
(c) Primula
b) Split-night temperatures
1) Fuel saving of six percent
2) No effect on quality of crops and production time
3) Optimum night temperatures until 11:00 p.m.
4) Temperature allowed to fall to 45°F (7°C) until dawn
5) Temperature increased and plants watered with warm water at dawn
c) Bottom heat
1) Soil heated to 65°F to 70°F (18°C to 21°C)
2) Air temperature reduced to 55°F (13°C)
3) Major renovation required of most greenhouse heating systems
d) Improved space utilization
1) Progressive spacing
(a) Space between pots increased only when needed
(b) 50 percent savings in bench space
2) Moveable benches - growing space increased by 25 percent
3) Multiple-shelf benches
(a) More production space in a given area than flat benches
(b) Pyramid or A-frame bench
(c) Low light-requiring plants on the bottom shelves
(d) Higher light-requiring plants on the top shelves

F. Other activity

Have students look through greenhouse supply catalogs and find examples of materials used to conserve energy in greenhouses.

G. Conclusion

Since a greenhouse functions like a giant radiator, heating fuel accounts for its second highest overhead cost. Therefore, greenhouse operators must do everything possible, considering both the outside and inside aspects of the greenhouse environment, to conserve energy in order to maximize profits.

H. Competency

Describe different modifications and procedures used to conserve energy in greenhouses.

I. Answers to Evaluation

1. c
2. c
3. a
4. b
5. d
6. c
7. a
8. e
9. c
10. b
11. a
12. g
13. f
14. d

UNIT II - GREENHOUSE OPERATION AND MANAGEMENT Name ____________________

Lesson 7: Energy Conservation Date ____________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Energy conservation is considered important in greenhouses because _________.

   a. An unlimited fuel supply is available
   b. Of decreasing costs of fuels
   c. The high fuel cost results in increased production costs
   d. Fuel cost is the highest overhead cost

2. Which of the following factors should not be considered when deciding the location and orientation of a greenhouse to conserve energy?

   a. Smallest cross section should face the prevailing winds
   b. Location from 38th parallel
   c. Type of greenhouse covering material
   d. Wind velocity and direction

3. Sixty percent porous windbreaks (such as evergreen trees) _________.

   a. Should never cast a shadow on the greenhouse
   b. Do not provide a protected area
   c. Result in a fuel savings of 50 to 75 percent
   d. Increase the wind velocity

Match the method of energy conservation with the cultural procedure.

_____ 4. lower night temperatures

_____ 5. split-night temperatures

_____ 6. bottom heat

_____ 7. improved space utilization

a. use of A-frame benches, moveable benches, or progressive spacing

b. plants like cineraria, calceolaria, or primula grown during the winter months

c. air temperature maintained at 55°F (13°C) and the soil heated to 65°F to 70°F (18°C to 21°C)

d. optimum night temperature maintained until 11:00 p.m., then allowed to fall to 45°F (7°C) until morning

Match the phrase on the right with the phrase on the left.

____ 8. double layer of polyethylene over glass

____ 9. laminated glazing material

____ 10. thermal blanket

____ 11. insulated sidewalls and foundations

____ 12. proper maintenance of the greenhouse and heating equipment

____ 13. conversion to a radiant heater

____ 14. air circulation fan

a. rigid Styrofoam® sheeting, Microfoam®, and bubble-pack material used to save fuel by three to six percent

b. reduces the amount of greenhouse space heated by forming an insulated barrier above and around the plants

c. expensive double-skinned material such as acrylic to replace existing cover

d. returns warm air downward from the attic

e. an inflated airspace created by blowers resulting in heat savings of 57 percent

f. combine with thermal blankets that run from ridge to eave to result in a fuel savings of more than 30 percent

g. covering vents, replacing broken glass, and adjusting the heating equipment to result in a fuel saving of three to ten percent

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 8: Plant Parts, Structures, and Functions

Objective: The student will be able to identify plant parts, structures, and functions.

Study Questions

1. **What are the functions of the parts of a plant cell?**
2. **What are the functions of the basic parts of a plant?**
3. **What are the functions of the specialized plant tissues?**
4. **What are the functions of the different types of roots?**
5. **What are hair roots and their functions?**
6. **What are the primary functions of stems?**
7. **What are the types of specialized stems?**
8. **What are the functions of the principal tissues of the leaf?**
9. **What are the functions the different types of modified leaves?**
10. **What are the functions of the parts of a flower?**
11. **How are complete and incomplete flowers different?**
12. **What are perfect and imperfect flowers?**
13. **What are the functions of the parts of a seed?**
14. **What are the general differences between monocots and dicots?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Masters
    - a) TM 8.1: Typical Plant Cell
    - b) TM 8.2: Parts of a Plant
    - c) TM 8.3: Types of Roots
    - d) TM 8.4: Specialized Stems
    - e) TM 8.5: Cross-Section of a Leaf
    - f) TM 8.6: Parts of a Complete Flower
    - g) TM 8.7: Longitudinal Views of Corn and Bean Seeds
    - h) TM 8.8: Dicots vs. Monocots
3. Assignment Sheets
    - a) AS 8.1: Parts and Functions of a Typical Plant Cell
    - b) AS 8.2: Parts and Functions of the Principal Tissues of the Leaf
    - c) AS 8.3: Parts and Functions of a Complete Flower
    - d) AS 8.4: Seed Part Identification

4. Movie

    a) "Cells of Plants and Animals." Academic Support Center Film Library, 505 East Stewart Rd., Columbia, MO 65201.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 8: Plant Parts, Structures, and Functions

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

To successfully produce plants, it is important to know the functions of the plant parts and structures. Upon completing this unit, the student will be able to name the major parts of plants and know the major functions of each part.

C. Assignment

D. Supervised study

E. Discussion

1. Have students discuss the parts of a plant cell and the functions of each part. Use TM 8.1. Consider showing the movie "Cells of Plants and Animals." Have students complete AS 8.1.

What are the functions of the parts of a plant cell?

a) Cell wall
    1) Primary wall - first part of the cell wall to develop
    2) Middle lamella - the layer between the walls of two cells
    3) Secondary wall - the woody part of the plant which develops inside the primary wall
b) Plasma membrane
    1) Membrane surrounding the cell, located just inside the cell wall
    2) Membrane composed of molecules of proteins, carbohydrates, and phospholipids (phosphorus and fat)
    3) Main functions
        (a) "Gatekeeper" to let some substances enter the cell easily by osmosis, while other substances are allowed to enter slowly or are blocked from entering (differentially permeable or selectively permeable); also controls exit of substances from the cell
        (b) Senses outside environmental conditions and sends this information to the nucleus of the cell
c) Cytoplasm
    1) Liquid contained within the cell
    2) Location for organelles (membrane-bound sacks)
    3) Complex substance which is the site of most life processes
d) Nucleus
    1) Organelle serving as the control center of the cell
    2) Location for genetic material (chromosomes)
    3) Functions
        (a) Control the physiological characteristics and appearance of the plant
        (b) Transmit hereditary characteristics to the offspring
e) Mitochondria
    1) Small dense organelles in the cytoplasm
    2) Functions
        (a) Control many of the chemical reactions in the cell

    - (b) Provide a site for respiration
- f) Plastids
  - 1) Small organelles within the cytoplasm that contain various pigments
    - (a) Chloroplasts - contain green pigment, or chlorophyll
    - (b) Chromoplasts - contain yellow, red, and orange pigment
  - 2) Function
    - (a) Chloroplasts are sites of the photosynthesis process.
    - (b) Chromoplasts provide color for flower petals and bracts.
- g) Vacuoles
  - 1) Large fluid-filled organelles in the cytoplasm
  - 2) Function - store water, dissolved minerals, and other materials
  - 3) Large central vacuole formed when vacuoles mature and join

2. Have students name parts of the plant; write them on the board. After determining parts discuss their functions. Use TM 8.2.

What are the functions of the basic parts of a plant?

- a) Roots
  - 1) Anchor the plant
  - 2) Absorb water and minerals
  - 3) Translocate water and minerals to the stem
  - 4) Store food
- b) Stems
  - 1) Translocate water, minerals, and food to the leaves
  - 2) Support the leaves and display them to light
  - 3) Store food
- c) Leaves
  - 1) Manufacture food through photosynthesis
  - 2) Provide site of gas exchange with the atmosphere
  - 3) Store food
- d) Flowers
  - 1) Contain organs specialized for sexual reproduction
  - 2) Produce seeds and fruit

3. Discuss with students the different specialized plant tissues and their functions.

What are the functions of the specialized plant tissues?

- a) Meristem tissues - cells that are actively dividing to form new growth
  - 1) Apical meristem tissues
    - (a) Located at the tips of roots and stems
    - (b) Function - increase the length of plants
  - 2) Cambium meristem tissues
    - (a) Located in the stems
    - (b) Function - increase the plant size in diameter
    - (c) Can actively divide after dormancy when a plant is propagated or wounded
  - 3) Intercalary zone meristem tissues
    - (a) Located just above the nodes in monocot plants only
    - (b) Function - increase stem height
- b) Permanent tissues - mature cells that are not actively dividing
  - 1) Epidermis tissues
    - (a) Located on outside covering of plants
    - (b) Function - protect and support the inner cells of the plant
  - 2) Vascular system tissues - continuous path from roots through stems to the leaves
    - (a) Xylem tissues - translocate water and dissolved minerals upward
    - (b) Phloem tissues - translocate food from leaves to stems and roots for storage, to meristem tissues for growth, and to all cells for immediate use

4. Show the roots of several different plants and discuss the functions of each. Use TM 8.3.

What are the functions of the different types of roots?

a) Tap root (e.g., carrot)
   1) Continuation of the primary root
   2) Ideal for anchorage
   3) Penetration to greater depth to obtain water
   4) Storage area for food manufactured by photosynthesis
b) Fibrous roots (e.g., grass)
   1) Many finely branched secondary roots
   2) Shallow roots that cover a large area of soil
      (a) More effective absorption of water and minerals
      (b) Roots that hold soil particles and help prevent erosion
c) Aerial roots
   1) Clinging air roots (e.g., English ivy)
      (a) Short roots that grow out horizontally from the stems
      (b) Roots that fasten the plant to a support
   2) Absorptive air roots (e.g., orchid)
      (a) Thick outer covering of dead tissue
      (b) Roots that absorb and store water
d) Aquatic roots (e.g., water lilies) - absorb oxygen and nutrients from water
e) Adventitious roots (e.g., blackberries)
   1) Develop in places other than nodes
   2) Can form on cuttings and rhizomes

5. Have students define hair roots and identify their functions.

What are hair roots and their functions?

a) Tiny one-celled hair-like extensions of the epidermal cells located near the tips of the roots where vascular tissues have formed
b) Functions
   1) Increase the surface area of roots for greater absorption
   2) Absorb water and dissolved minerals from the soil

6. Have the students list the functions of stems. List the functions of stems on the board.

What are the primary functions of stems?

a) Support branches
b) Support leaves
c) Support flowers
d) Support seeds
e) Support fruit
f) Give the plant height and expose it to sunlight
g) Provide a site for photosynthesis, in special cases
h) Store food
i) Contain tissues that translocate water, dissolved minerals, and food manufactured during photosynthesis

7. Have students give examples of different types of stems. List the functions on the board. Use TM 8.4.

What are the types of specialized stems?

a) Corm (e.g., gladiolus, crocus)
   1) Solid, fleshy, scale-covered enlargement
   2) Underground stem

- b) Bulb (e.g., tulips, lilies, onions)
  - 1) Layers of fleshy scales that overlap each other
  - 2) Underground stem
- c) Tuber (e.g., potatoes, caladiums)
  - 1) Short, thick, underground stem
  - 2) Food storage area
- d) Crown (e.g., African violets, fern)
  - 1) Closely grouped stems or plantlets
  - 2) Just above or below ground line
- e) Spurs (e.g., pear and apple trees) - short stems found on woody plant limbs adapted for increased production of fruits
- f) Rhizomes (e.g., lily-of-the-valley, iris) - underground stems that produce roots on the lower surface and extend leaves and flower shoots above the ground
- g) Stolon (e.g., strawberry, airplane plant) - stem that grows horizontally above the soil surface

8. Have the students list the principal tissues of the leaf. List the function of each tissue on the board. Use TM 8.5. Have students complete AS 8.2.

What are the functions of the principal tissues of the leaf?

- a) Epidermis - upper and lower
  - 1) Cuticle
    - (a) Waxy substance covering the epidermis of leaves and stems
    - (b) Waterproof layer that keeps water in plants
  - 2) Stomata
    - (a) Openings in the epidermis mainly located on the underside of leaves
    - (b) Exchange of gases such as carbon dioxide, oxygen, and water vapor
  - 3) Guard cells
    - (a) Two cells located on each side of a stomate
    - (b) Function to open and close the stomate
- b) Mesophyll layer
  - 1) Palisade mesophyll
    - (a) Elongated cells under the upper epidermis which contain chloroplasts
    - (b) Primary site of photosynthesis
  - 2) Spongy mesophyll
    - (a) Between the palisade mesophyll tissues and the lower epidermis
    - (b) Mass of irregularly shaped cells which contain chloroplasts interspersed with many air spaces
    - (c) Site of photosynthesis and gas exchange
- c) Veins or vascular bundles - in the spongy mesophyll
  - 1) Phloem tissues conduct food from the site of photosynthesis to the rest of the plant.
  - 2) Xylem tissues conduct water and dissolved minerals up to the photosynthesizing cells in the leaves and stem.

9. Discuss with students modified leaves and their functions. Have some examples or pictures of plants that have modified leaves to show the students.

What are the functions of the different types of modified leaves?

- a) Scales (e.g., juniper)
  - 1) Hard, plate-like structures of woody plants
  - 2) Function - protect the bud during the winter
- b) Bracts - colored leaves near the flowers or fleshy leaves
  - 1) Leafy bracts (e.g., poinsettias, dogwoods) - attract pollinating insects
  - 2) Fleshy bracts (e.g., globe artichoke) - store nourishment for the seed

c) Tendrils (e.g., grapevines, morning glory)
    1) Slender, threadlike modified leaves that twine
    2) Function - support and anchor the plant
d) Thorns (e.g., rose)
    1) Short, hard, modified leaves with a sharp point
    2) Function - protect the plant
e) Sacs (e.g., sundews, Venus fly-trap)
    1) Pouch-like modified leaf
    2) Function - hold water and catch insects

10. Have students observe examples of complete flowers and describe the function of each part. Use TM 8.6. Have students complete AS 8.3.

What are the functions of the parts of a flower?

a) Sepals - vegetative part
    1) Outer covering of the flower bud
    2) Collective name - calyx
    3) Function - protect the stamens and pistils when the flower is in bud stage
b) Petals - vegetative part
    1) Usually brightly colored
    2) Collective term - corolla
    3) Functions
        (a) Protect the stamen and pistils in bud stage
        (b) Attract pollinating insects
c) Stamens - male reproductive part
    1) Anther - produces pollen grains
    2) Filament - supports the anther
d) Pistil - female reproductive part
    1) Ovary
        (a) Enlarged portion at the base of the pistil
        (b) Function - produces ovules which will develop into seeds; site for fertilization
    2) Stigma - receives and holds the pollen grains
    3) Style
        (a) Connects the stigma with the ovary
        (b) Function - supports the stigma so that it may be pollinated

11. Discuss with students the difference between complete and incomplete flowers. List examples of some incomplete flowers.

How are complete and incomplete flowers different?

a) Complete flowers have all four main parts of a flower.
    1) Sepals
    2) Petals
    3) Stamens
    4) Pistils
b) Incomplete flowers are missing one or more of the main parts of a flower.
    1) Apetalous - has no petals
    2) Staminate - male flower only (female parts missing)
    3) Pistillate - female flower only (male parts missing)
    4) Absence of sepals

12. Discuss with students the difference between perfect and imperfect flowers. List some imperfect flowers on the board.

What are perfect and imperfect flowers?

a) Perfect flowers (e.g., lilies)

    1) Perfect flowers contain both male and female parts, stamens and pistil.
    2) Perfect flowers are often self-pollinating.
- b) Imperfect flowers (e.g., cucumber)
    1) Imperfect flowers contain male or female parts.
        (a) Staminate flower - A staminate flower is an imperfect flower that contains only male parts, the stamens.
        (b) Pistillate flower - A pistillate flower is an imperfect flower that contains only female parts, the pistils.
    2) Imperfect flowers often cross-pollinate.

13. Have the students list the parts of a seed and discuss the functions of each part. Use TM 8.7. Have students complete AS 8.4.

What are the functions of the parts of a seed?

- a) Seed coat
    1) Hard exterior surface of the seed
    2) Functions
        (a) Prevents the seed from drying out
        (b) Protects the embryo from mechanical injury
- b) Embryo - miniature plant contained within the seed coat
    1) Epicotyl (plumule)
        (a) Growth bud of the embryo located above the cotyledons
        (b) Functions - develops into the shoot that emerges from the germinating seed
    2) Hypocotyl - stem section located below the cotyledons
        (a) First true stem
        (b) Function - as it lengthens the cotyledons and epicotyl emerge from the germinating seed
    3) Radicle (root tip) - growing point of the root
        (a) Located at the end of the hypocotyl
        (b) First root of the plant
        (c) First part to emerge from the germinating seed
        (d) Functions
            (1) Holds the developing plant in the soil
            (2) Absorbs water and nutrients from the soil
    4) Cotyledons - first leaf or leaves
        (a) Seed leaves
            (1) Monocotyledonous plants (monocots) have one cotyledon.
            (2) Dicotyledonous plants (dicots) have two cotyledons.
        (b) Functions
            (1) Monocot - protects the epicotyl
            (2) Dicot - protects the epicotyl and is a food storage area for new plants
- c) Endosperm - food storage tissues which nourish the developing embryo upon germination; present in monocot seeds only

14. Discuss with students the two types of seedling plants. List the differences on the board. Use TM 8.8.

What are the general differences between monocots and dicots?

- a) Monocots (e.g., corn, grass, lilies)
    1) One cotyledon
    2) Leaves with parallel veins
    3) Vascular bundles scattered at random within the stems
    4) Flowers that have parts in threes or multiples of threes (e.g., three stamens, six petals)
- b) Dicots (e.g., most flowering plants, deciduous trees, shrubs)
    1) Two cotyledons
    2) Leaves with a branched network of veins

        3) Stems with vascular bundles in a ring pattern
        4) Flower parts in fours or fives or multiples of four or five

F. Other activities

1. Have examples of complete flowers which the students can dissect. Have the students show the instructor each part of a flower.

2. Soak lima beans and corn seeds in water. Have the students dissect both types of seeds, pointing out each part to the instructor.

G. Conclusion

In order to understand growth, reproduction, and all the other processes occurring within the plant, it is important to understand some basic concepts of plant cell structure, plant anatomy (gross structure), and plant physiology (functions of the various parts).

H. Competency

Identify plant parts, structures, and functions.

I. Answers to Evaluation

1.	e	11.	a
2.	b	12.	b
3.	a	13.	d
4.	d	14.	d
5.	h	15.	c
6.	c	16.	b
7.	g	17.	e
8.	c	18.	b
9.	a	19.	j
10.	b	20.	g

J. Answers to assignment sheets

1. AS 8.1 - Parts and Functions of a Plant Cell

    1. Cell wall - made up of three parts; support of plant
    2. Chloroplasts - contain chlorophyll needed to carry on photosynthesis process
    3. Vacuole - storage area for water, dissolved minerals, and other material
    4. Cytoplasm - complex, liquid substance containing the organelles which are responsible for carrying out most cellular metabolism
    5. Mitochondria
        a) Controls many of the chemical reactions in the cell
        b) Responsible for respiration
    6. Nucleus
        a) Control center of the cell
        b) Contains genetic material - controls physiological characteristics and appearance of the plant
        c) Transmits hereditary characteristics to the offspring

2. AS 8.2 - Parts and Functions of the Principal Tissues of the Leaf

    1. Cuticle - forms a waterproof layer that keeps water in plant
    2. Upper epidermis - protective covering layer
    3. Xylem tissues - translocates water and dissolved minerals up to the leaves
    4. Phloem tissues - translocates food from the photosynthesizing cells to the rest of the plant

5. Vascular bundle or vein - translocates water, dissolved minerals, and manufactured food
6. Stomate - exchanges gases and water vapor between leaf interior and atmosphere
7. Guard cells - open and close the stomate
8. Mesophyll tissues - site of photosynthesis and gas exchange
9. Spongy mesophyll - photosynthesis and gas exchange
10. Palisade mesophyll - contains chlorophyll, primary site of photosynthesis

3. AS 8.3 - Parts and Functions of a Flower

a. Petals - attracts pollinators, protects stamen and pistil in the bud stage
b. Anther - produces pollen grains
c. Filament - supports the anther
d. Stamen - collectively, the male part of the flower
e. Sepal - protects the stamen, pistils, and petals in bud stage
f. Ovary - produces ovules (eggs)
g. Style - supports the stigma and allows it to be pollinated
h. Stigma - receives and holds the pollen grains
i. Pistil - collectively, the female part of the flower

4. AS 8.4 - Seed Part Identification

a. Seed coat
b. Epicotyl or plumule
c. Hypocotyl
d. Radicle or root tip
e. Embryo
f. Cotyledon
g. Dicot
h. Seed coat
i. Endosperm
j. Cotyledon
k. Epicotyl or plumule
l. Hypocotyl
m. Radicle or root tip
n. Embryo
o. Monocot

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ____________________

Lesson 8: Plant Parts, Structures, and Functions Date ____________________

EVALUATION

Match the term with the description.

____ 1. nucleus

____ 2. mitochondria

____ 3. chloroplasts

____ 4. epidermis

____ 5. stomata

____ 6. spongy mesophyll

____ 7. xylem tissues

a. small organelles within the cytoplasm that contain chlorophyll needed to carry on photosynthesis

b. small dense organelles in the cytoplasm which provide a site for respiration

c. mass of irregularly-shaped leaf cells that contain chloroplasts where photosynthesis and gas exchange occurs

d. the protective outer covering of the plant

e. control center of the cell, contains the chromosomes which control the genetic inheritance of the plant

f. translocate food from the photosynthesizing cells to the rest of the plant

g. translocate water and dissolved minerals up to the photosynthesizing cells

h. openings in the epidermis where gases and water vapor are exchanged

Circle the letter that corresponds to the best answer.

8. ____________________ are brightly colored leaves that attract pollinators.

   a. Sacs
   b. Stems
   c. Bracts
   d. Tendrils

9. Which of the following terms is not a part of the seed embryo?

   a. Endosperm
   b. Epicotyl
   c. Hypocotyl
   d. Radicle

10. Permanent tissues are ____________________.

   a. Cells that are actively dividing
   b. Mature cells that are not actively dividing
   c. Middle-aged cells that have slowed down
   d. Permanently mature cells that cannot become meristem

11. Xylem tissues, part of the vascular system of a plant, translocate __________.

a. Water and dissolved minerals to the photosynthesizing cells
b. Water and dissolved nutrients to the stems and roots
c. Manufactured plant food from the leaves
d. Manufactured plant food to the leaves

12. Complete flowers have the following parts: __________.

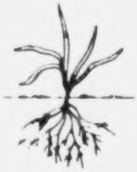
a. Sepals, petals, stamens, and receptacle
b. Sepals, petals, stamens, and pistils
c. Sepals, petals, receptacle, and pistils
d. Sepals, receptacle, stamens, and pistils

13. Apetalous, staminate, and pistillate flowers are __________ flowers.

a. Complete
b. Perfect
c. Non-functional
d. Incomplete

14. A ______________________ root system is pictured below.

a. Aerial
b. Adventitious
c. Aquatic
d. Fibrous



15. Which of the following is a short woody stem adapted for fruit production?

a. Corm
b. Rhizome
c. Spur
d. Stolen

16. Which of the following is an underground stem that has roots on the lower surface and extends leaves and flower shoots above the ground?

a. Crown
b. Rhizome
c. Stolon
d. Tuber

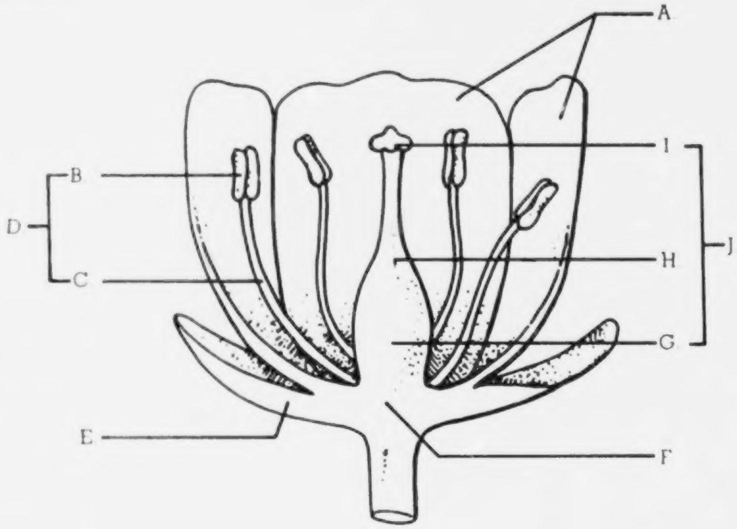
Identify the parts of a flower.

___ 17. sepal

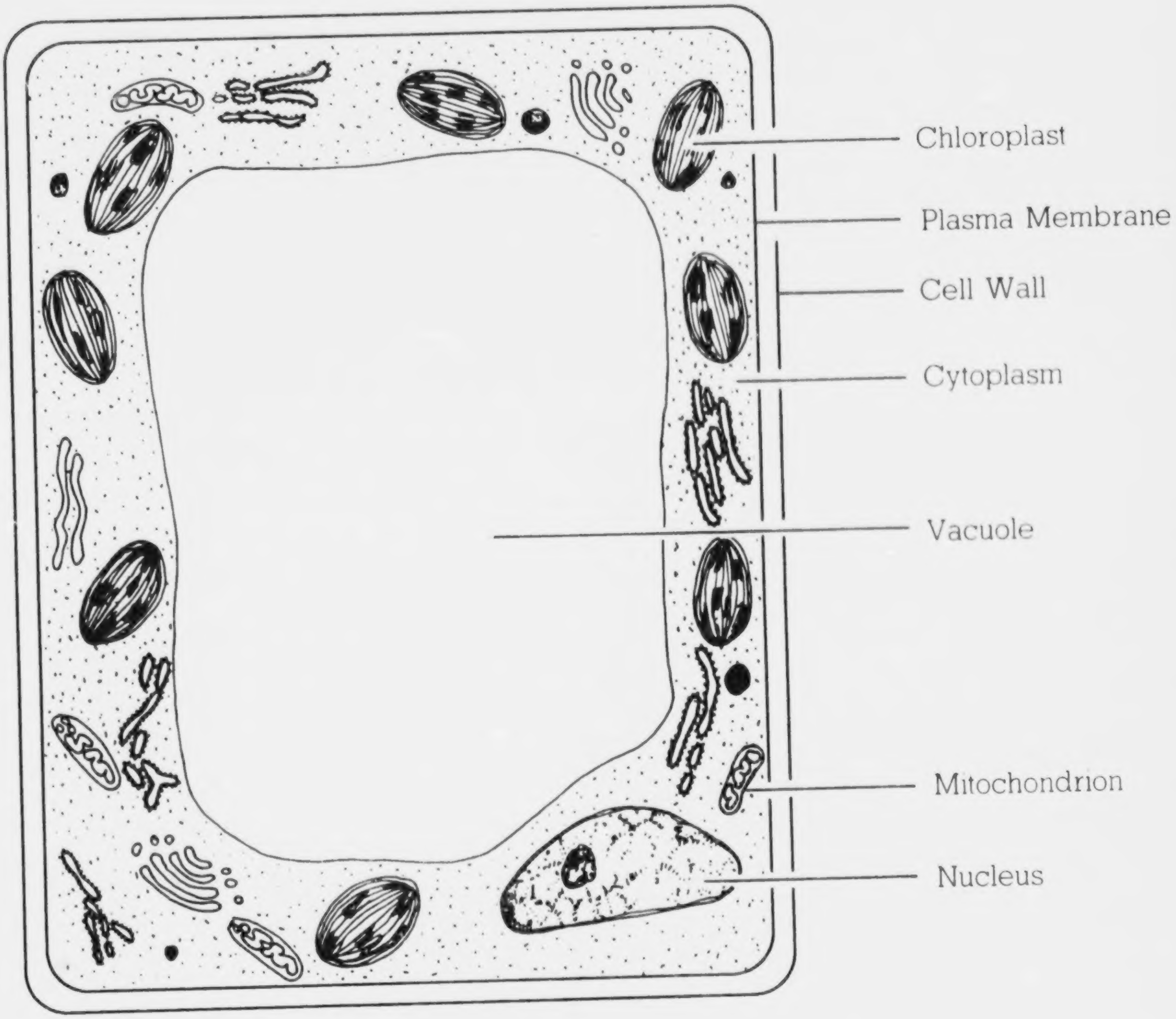
___ 18. anther

___ 19. pistil

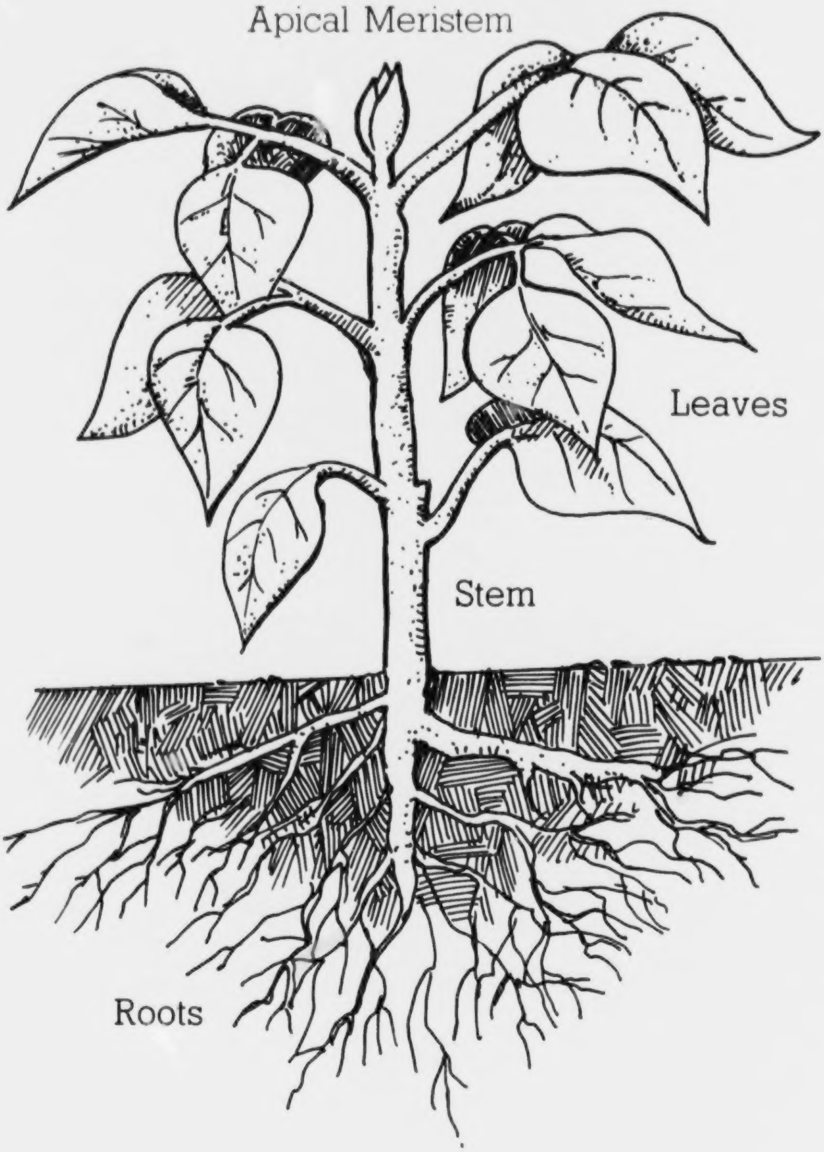
___ 20. ovary



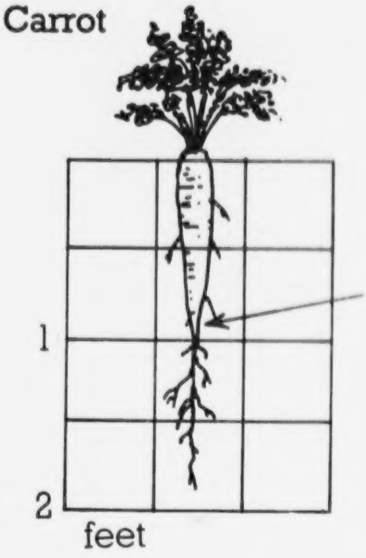
Typical Plant Cell

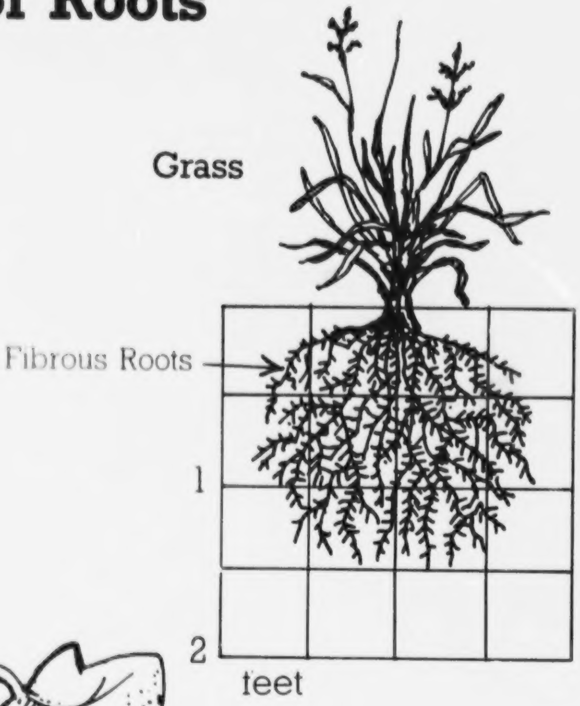

Chloroplast
Plasma Membrane
Cell Wall
Cytoplasm
Vacuole
Mitochondrion
Nucleus

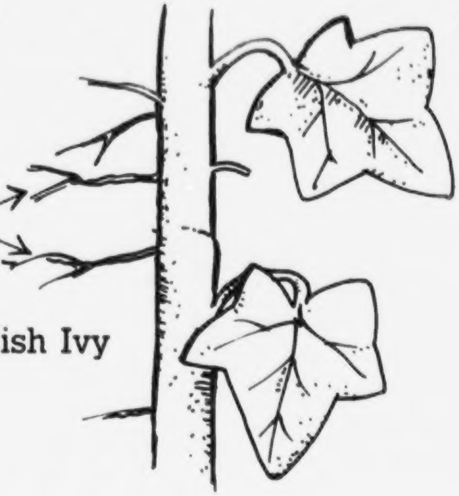
Parts of a Plant

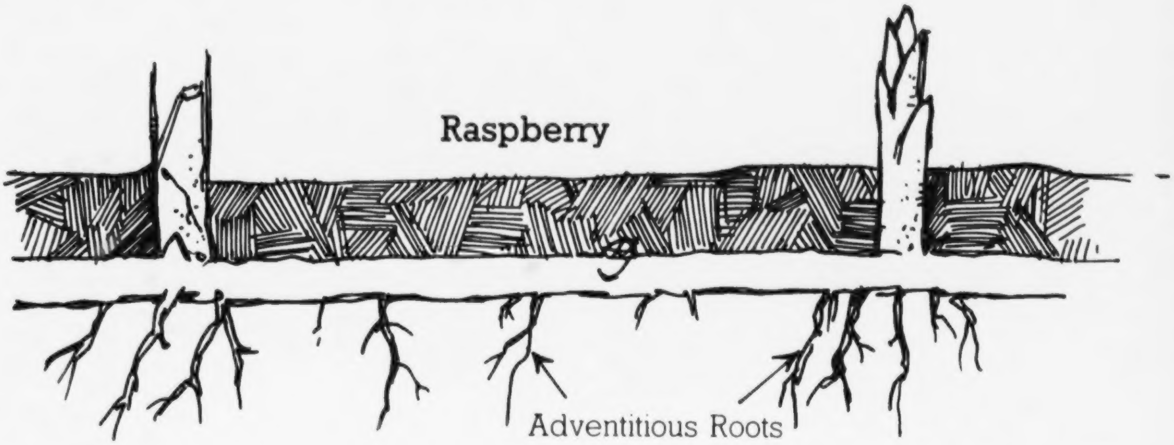

Apical Meristem
Leaves
Stem
Roots

Types of Roots

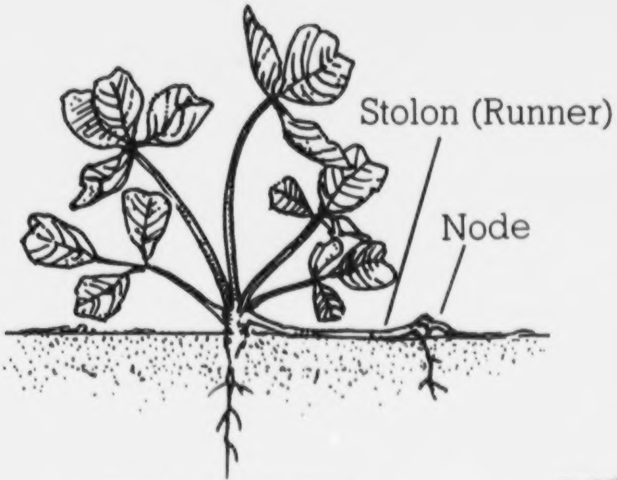

Carrot
Tap Root
1
2
feet


Grass
Fibrous Roots
1
2
feet

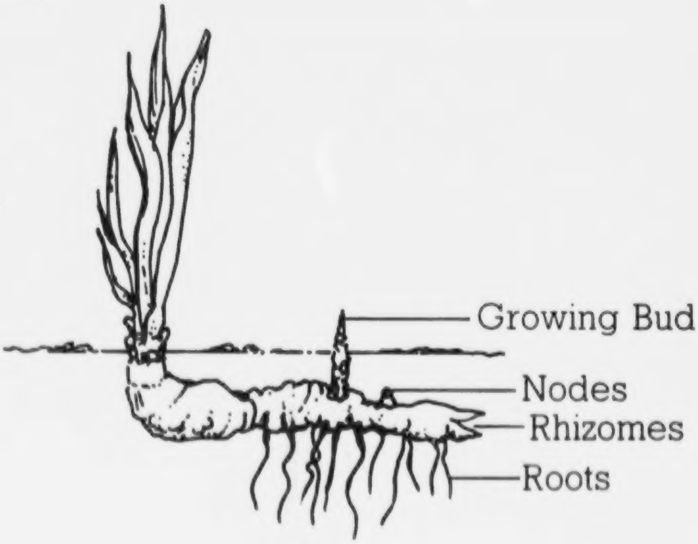

Aerial Roots
English Ivy


Raspberry
Adventitious Roots

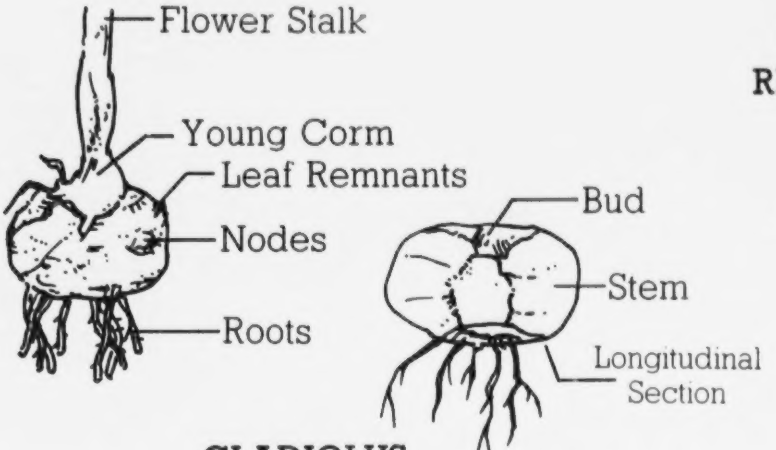
Specialized Stems


Stolon (Runner)
Node

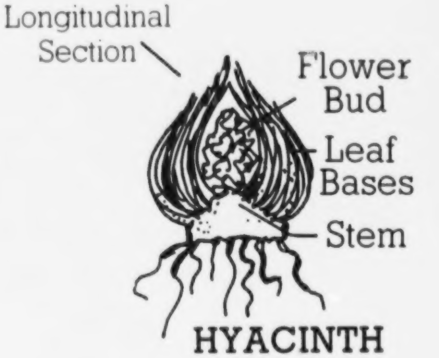
STRAWBERRY
Stolon


Growing Bud
Nodes
Rhizomes
Roots

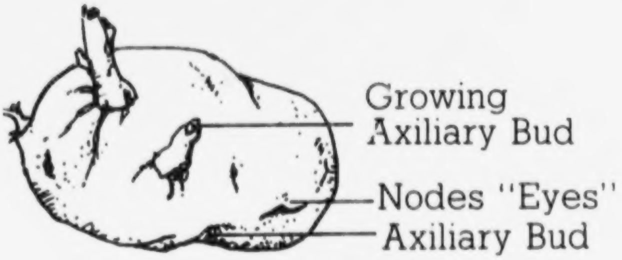
IRIS
Rhizome


Flower Stalk
Young Corm
Leaf Remnants
Nodes
Roots
Bud
Stem
Longitudinal Section

GLADIOLUS
Corm

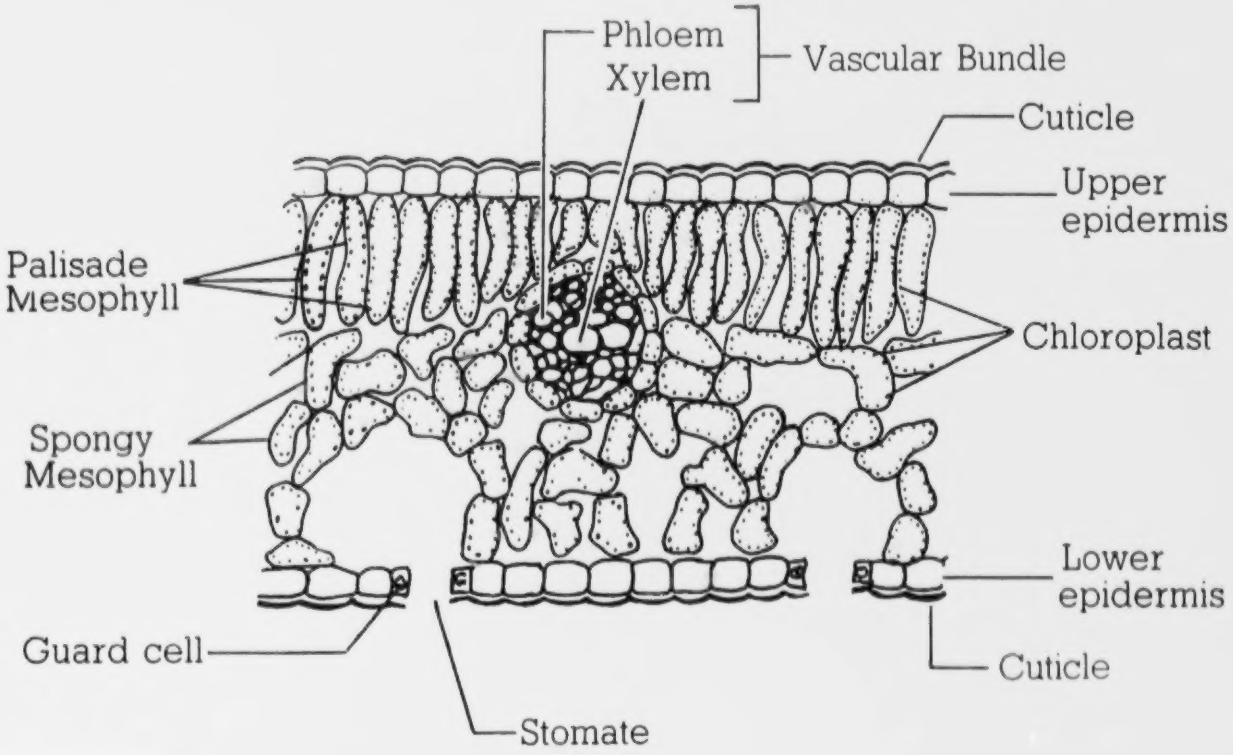

Longitudinal Section
Flower Bud
Leaf Bases
Stem

HYACINTH
Bulb

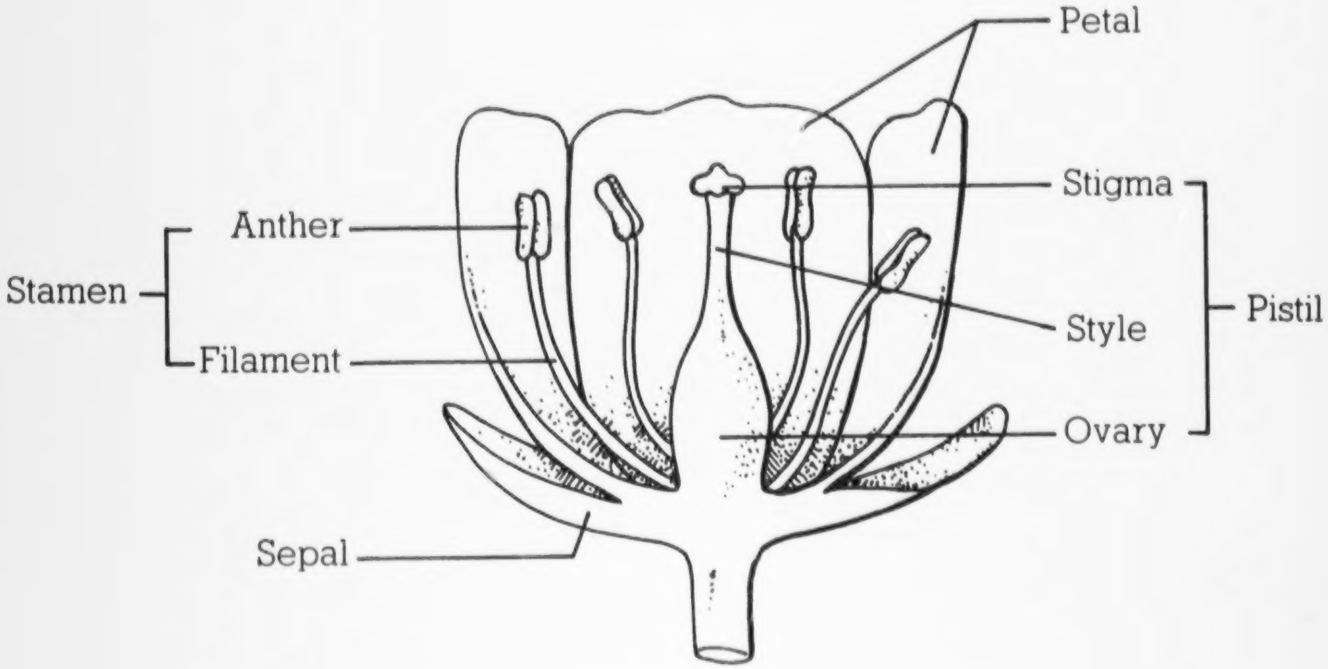

Growing Axiliary Bud
Nodes "Eyes"
Axiliary Bud

POTATO
Tuber

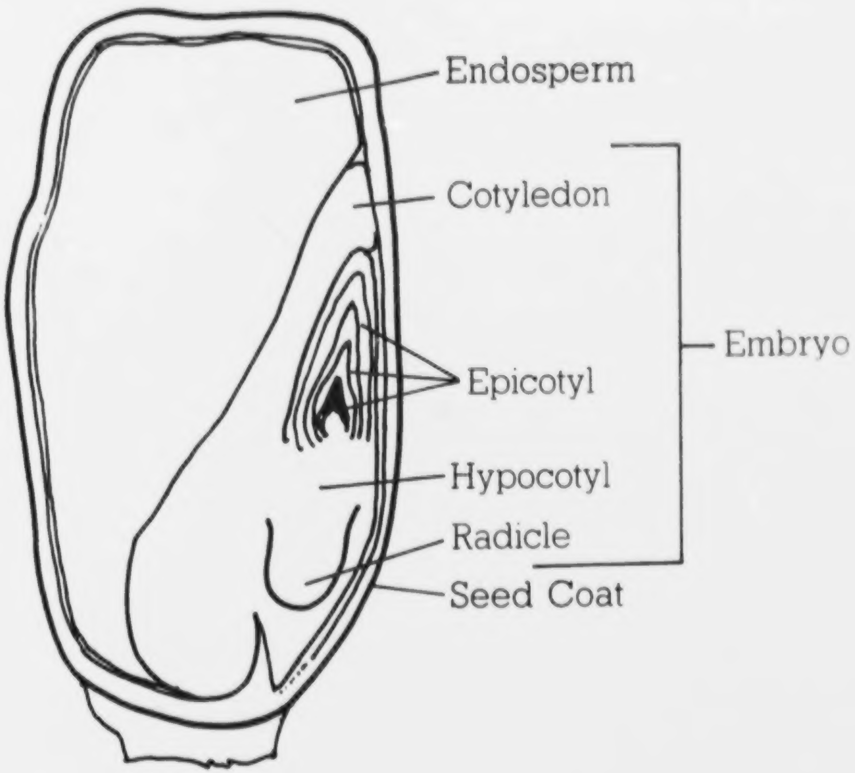
Cross-Section of a Leaf


Phloem
Xylem
Vascular Bundle
Cuticle
Upper epidermis
Palisade Mesophyll
Chloroplast
Spongy Mesophyll
Lower epidermis
Guard cell
Cuticle
Stomate

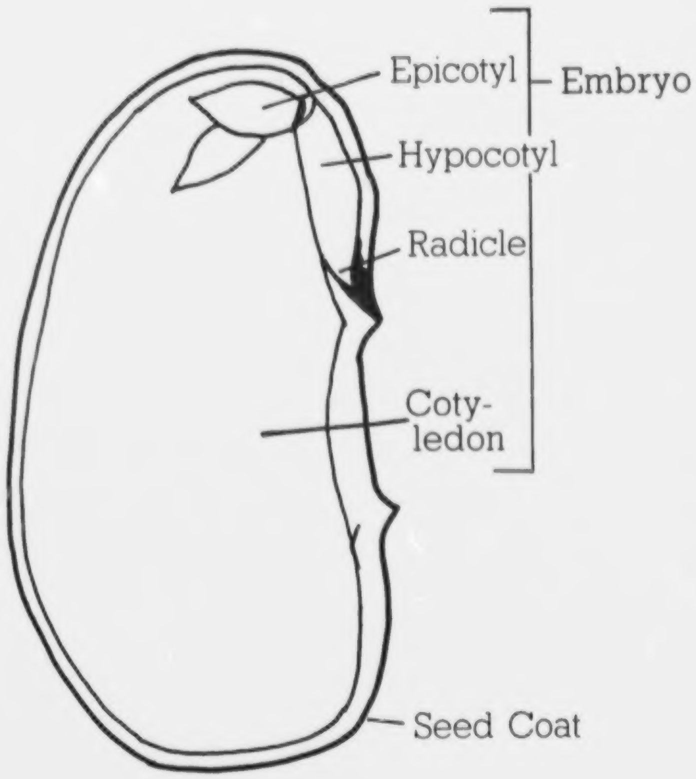
Parts of a Complete Flower


Petal
Anther
Stigma
Stamen
Style
Pistil
Filament
Ovary
Sepal

Longitudinal Views of Corn and Bean Seeds


Endosperm
Cotyledon
Embryo
Epicotyl
Hypocotyl
Radicle
Seed Coat

CORN SEED (Monocot)


Epicotyl
Embryo
Hypocotyl
Radicle
Coty-
ledon
Seed Coat

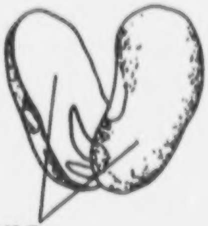
BEAN SEED (Dicot)

TM 8.7

TM 8.8

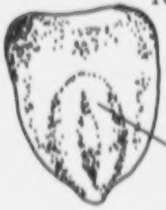
Dicots vs. Monocots

DICOT (e.g., Bean)

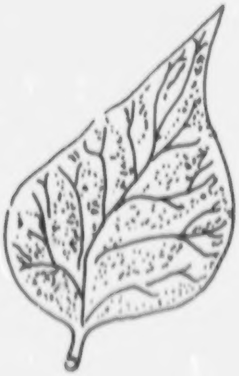


Two cotyledons

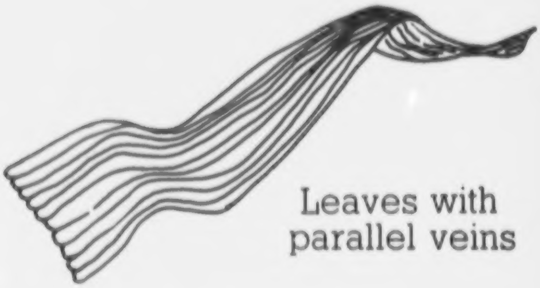
MONOCOT (e.g., Corn)



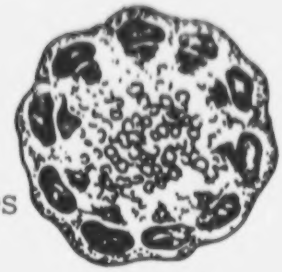
One cotyledon



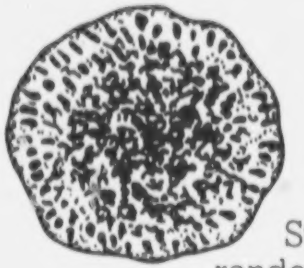
Leaves with
network of veins



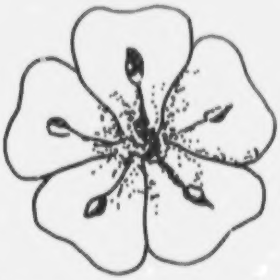
Leaves with
parallel veins



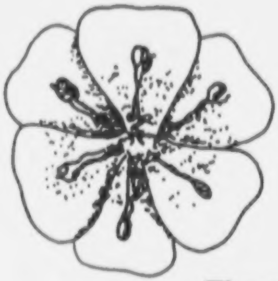
Stems with
vascular bundles
in a ring



Stems with
randomly scattered
vascular bundles



Flower parts in 4's or 5's
or multiple of 4 or 5



Flower parts in 3's
or multiples of 3

Parts and Functions of a Typical Plant Cell

1. ____________________

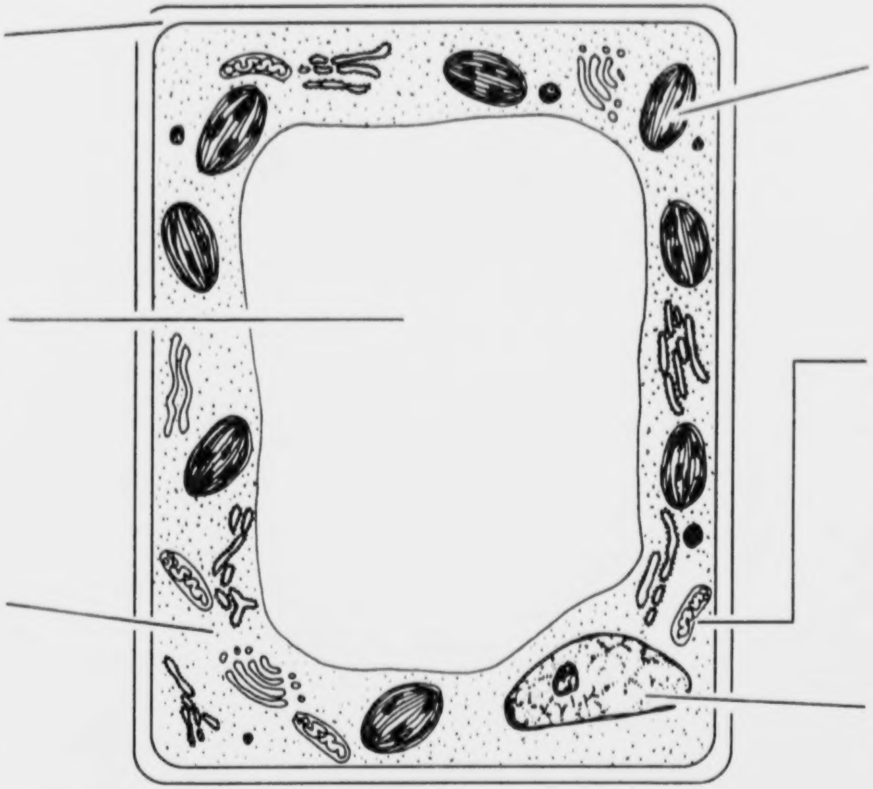
Function ____________________

2. ____________________

Function ____________________

3. ____________________

Function ____________________



4. ____________________

Function ____________________

5. ____________________

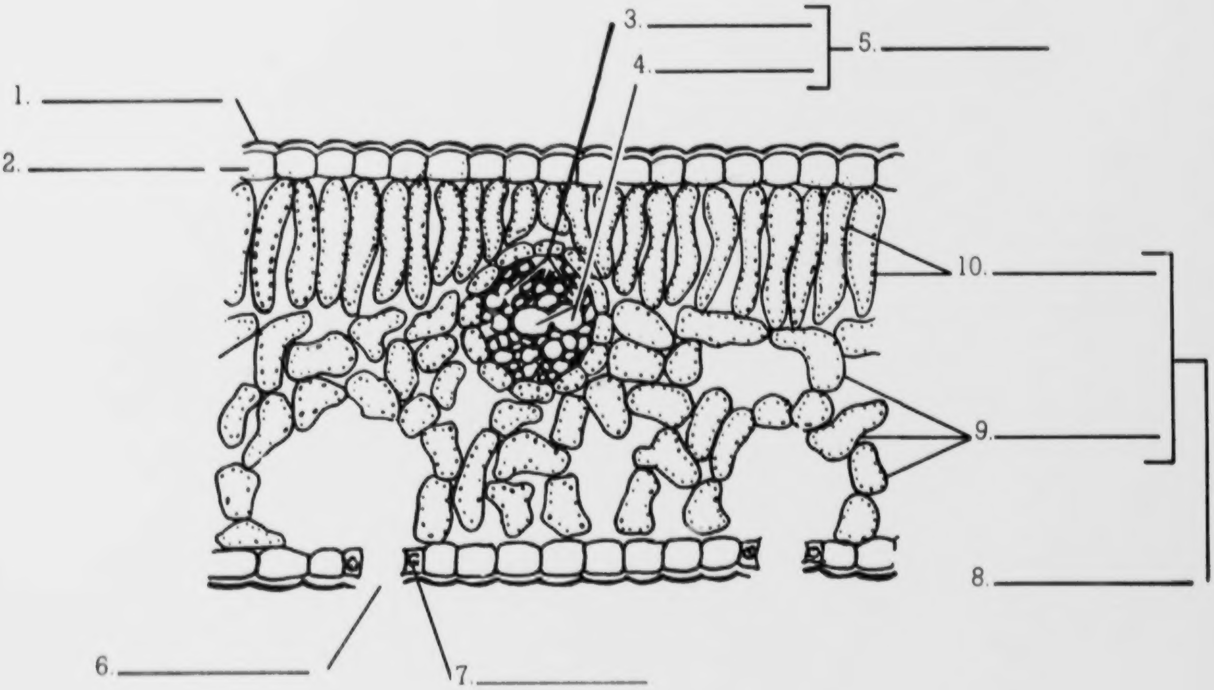
Function ____________________

6. ____________________

Function ____________________

AS 8.2

Parts and Functions of the Principal Tissues of the Leaf


3.
4.
5.
1.
2.
10.
9.
8.
6.
7.

Functions:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

7. ______________________________

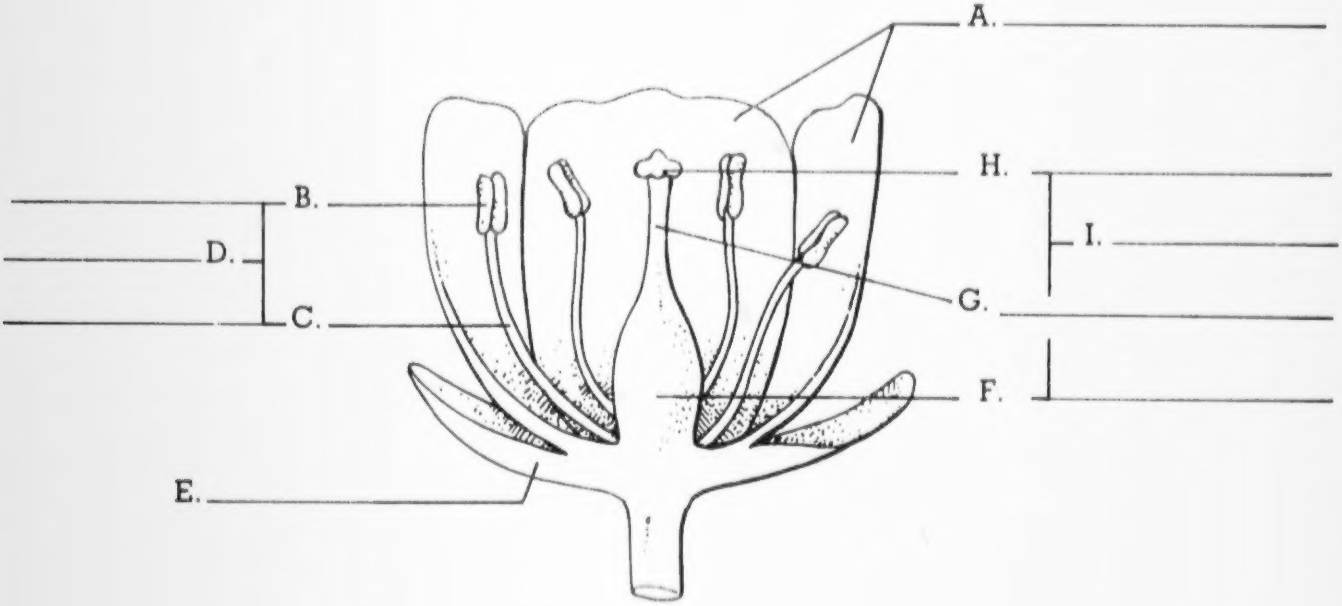
8. ______________________________

9. ______________________________

10. ______________________________

Parts and Functions of a Complete Flower

Label the parts of a complete flower and give their functions below.



Functions:

A. ______________________________

B. ______________________________

C. ______________________________

D. ______________________________

E. ______________________________

F. ______________________________

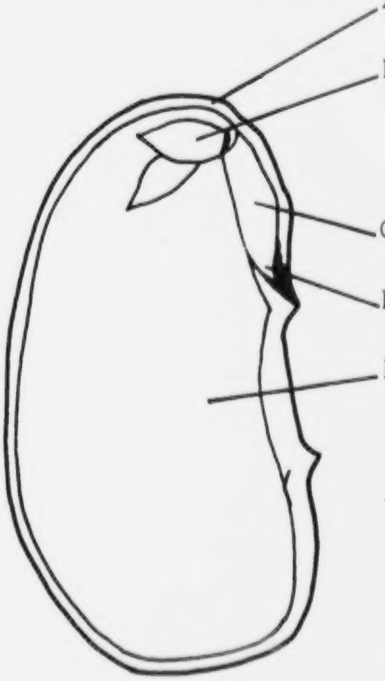
G. ______________________________

H. ______________________________

I. ______________________________

Seed Part Identification

Identify which seed is a monocot and which seed is a dicot (lines G and O) and identify the parts of each seed.



A. ____________________

B. ____________________

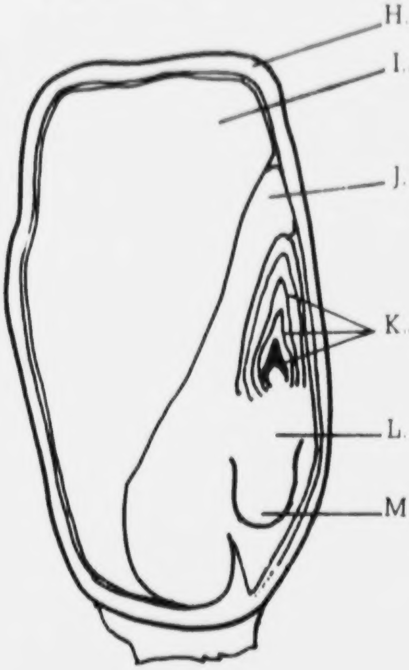
C. ____________________

D. ____________________

E. ____________________

F. ____________________

G. ____________________



H. ____________________

I. ____________________

J. ____________________

K. ____________________

L. ____________________

M. ____________________

N. ____________________

O. ____________________

Lesson 9: Plant Processes

Objective: The student will be able to describe the processes involved with plant growth.

Study Questions

1. **What are the basic processes that plants depend upon for growth?**
2. **What is photosynthesis?**
3. **What are the simplified steps in the photosynthesis process?**
4. **What is cellular respiration?**
5. **Why is cellular respiration considered a basic life process?**
6. **How is water absorbed by plants?**
7. **What is translocation, and how does it occur within the plant?**
8. **What is transpiration?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Masters
    a) TM 9.1: Photosynthesis
    b) TM 9.2: Photosynthesis vs. Respiration
    c) TM 9.3: Absorption and Transpiration
3. Movies (Available from the Academic Support Center Film Library, 505 East Stewart Road, Columbia, MO, 65211).
    a) "Photosynthesis"
    b) "Photosynthesis and the Respiration Cycle"

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 9: Plant Processes

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

It is important to understand how plant processes occur and how these processes affect plant growth. The photosynthetic process produces food for the plant. Cellular respiration is the breaking down of this food to yield energy required for cell metabolism. Water absorption, translocation, and transpiration deal with the movement of water into, within, and out of the plant. All five of these plant processes have a direct effect on plant growth and quality.

C. Assignment

D. Supervised study

E. Discussion

1. Ask students to list the five growth processes in plants. List them on the board.

   What are the basic processes that plants depend upon for growth?

   a) Photosynthesis
   b) Cellular respiration
   c) Water absorption
   d) Translocation
   e) Transpiration

2. Ask students to explain photosynthesis, including the formula. Write the formula on the board.

   What is photosynthesis?

   Photosynthesis is the process by which green living plants convert carbon dioxide and water in the presence of light into simple sugars. The formula for photosynthesis:

$$\underset{\text{(carbon dioxide)}}{6\ CO_2} + \underset{\text{(water)}}{6\ H_2O} \xrightarrow[\text{light energy}]{\text{chlorophyll}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6\ O_2}$$

3. Ask students to list the steps in the photosynthesis process (TM 9.1). Consider showing the movies "Photosynthesis" and "Photosynthesis and the Respiration Cycle."

   What are the simplified steps in the photosynthesis process?

   a) Carbon dioxide gas enters the plant through stomata, which are primarily located on leaves.
   b) Water is absorbed by the hair roots and is transported to the leaves by the xylem tissues.
   c) Light strikes the chlorophyll contained in the chloroplasts in the mesophyll cells of the leaf and stem.

d) Light energy is absorbed.
e) Chemical reactions take place that convert the hydrogen from water, along with carbon dioxide, to a simple sugar called glucose.
f) The glucose is transported by the phloem tissues to other parts of the plant.
g) Oxygen is released through stomata.

4. Ask students to explain cellular respiration, including the formula. Write the formula on the board.

What is cellular respiration?

Cellular respiration is the controlled breaking down of glucose, releasing energy for plant growth, absorption, translocation, and many other metabolic processes. The formula for aerobic respiration is:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6\,O_2} \longrightarrow \underset{\text{(carbon dioxide)}}{6\,CO_2} + \underset{\text{(water)}}{6\,H_2O} + \text{Energy}$$

5. Discuss with students why cellular respiration is considered a basic life process. TM 9.2 illustrates the major differences between photosynthesis and respiration.

Why is cellular respiration considered a basic life process?

a) Cellular respiration enables the plant cell to release energy which is then used in many energy-requiring chemical reactions within the cell.
b) Respiration releases H_2O and CO_2 into the atmosphere.

6. Ask students how plants absorb water. Use TM 9.3.

How is water absorbed by plants?

a) Hair roots take up water containing dissolved minerals from the soil by the process of absorption.
b) The movement of water and nutrients from the soil into the root cells is by the process of osmosis.

7. Discuss with students what translocation is and how it occurs within the plant.

What is translocation, and how does it occur within the plant?

a) Translocation is the movement of water soluble organic materials and mineral nutrients within the plant.
b) Translocation occurs within the vascular system, which consists of xylem and phloem tissues. Water translocation is primarily upward through the xylem, while food (i.e. glucose) translocation through the phloem is from the leaves to the rest of the plant, including the root system.

8. Explain to students that the process of translocation in plants is similar to sucking soda up a straw (i.e. an unbroken chain of soda molecules exists between the cup and the mouth). In comparison, plants undergoing transpiration will pull water via the xylem tissues from the roots up the stem and out the leaves. As water exits a leaf, the leaf's internal pressure is decreased, thus exerting a pulling force on the xylem to supply more water in order to maintain the unbroken chain of water molecules from root intake to exit through stomata.

What is transpiration?

a) Transpiration is the loss of water by evaporation. While transpiration primarily occurs from the leaf surfaces, water is also evaporated from stems and petals.

b) When a plant opens its stomata to take in CO_2, water vapor is released and transpiration occurs.

c) Environmental factors such as light, temperature, relative humidity, and wind influence transpiration rate.

F. Other activities

1. Demonstrate the process of translocation by placing freshly cut ends of celery stalks into a container filled with warm water and red food color. Soak the celery until the xylem tissues translocate the colored water upward. The leaf veins will indicate this when they turn from clear/light green to red. Then cut the stalk crosswise and locate the red-stained xylem tissues.

2. Demonstrate the process of osmosis. Fill two glasses with water and dissolve a tablespoon of salt into one of them. Place a slice of white potato into the salt water for 15 to 20 minutes. Remove the slice and observe that some of the cell water of the potato has moved from the area of high water concentration in the cells to the less concentrated salt solution, making the potato soft and flabby. In other words, the potato cells lose water. At the same time, salt molecules are moving into the cells of the slice of potato. However, they will move at a very slow rate because the plasma membrane of the cells is differentially permeable, allowing very slow inward passage of the salt. Place the same slice of potato in the other glass of water. It will regain its firmness.

3. Demonstrate the effects of light on photosynthesis. Place two whole potatoes into containers of water, allowing 1/3 of the potato to remain above the water. Place one of the containers in a location where it receives full sunlight. Place the other potato in a cabinet or closet where it receives no light. Allow the potatoes to sprout and produce leaves. Compare the color of the leaves and the length of the stems.

G. Conclusion

Green plants depend on the following five processes for growth: photosynthesis, cellular respiration, water absorption, translocation, and transpiration.

H. Competency

Describe the plant processes involved with plant growth.

I. Answers to Evaluation

1. e
2. b
3. f
4. a
5. g
6. c
7. d
8. c
9. a
10. b
11. e
12. d
13. $$\underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6\ O_2} \longrightarrow \underset{\text{(carbon dioxide)}}{6\ CO_2} + \underset{\text{(water)}}{6\ H_2O} + \text{Energy}$$

14. $\underset{\text{(carbon dioxide)}}{6\,CO_2} + \underset{\text{(water)}}{6\,H_2O} \xrightarrow[\text{light energy}]{\text{chlorophyll}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6\,O_2}$

15. b
16. d
17. c
18. b

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ____________

Lesson 9: Plant Processes Date ____________

EVALUATION

Rank the steps in the photosynthesis process in the correct order by placing the letter of each step on the right side beside the correct step number on the left.

Step 1 _____

Step 2 _____

Step 3 _____

Step 4 _____

Step 5 _____

Step 6 _____

Step 7 _____

a. Light energy is absorbed.

b. Water enters the leaf by the xylem tissues.

c. Glucose is produced and transported by the phloem tissues to other parts of the plant.

d. Oxygen is released through the stomata.

e. Carbon dioxide enters the leaf through the stomata.

f. Light strikes the chloroplast in the palisade mesophyll of the leaf.

g. A reaction takes place involving CO_2 and H_2O.

Match the term with the definition.

_____ 8. photosynthesis

_____ 9. cellular respiration

_____ 10. absorption

_____ 11. translocation

_____ 12. transpiration

a. the controlled breaking down of glucose resulting in energy for plant metabolism

b. the movement of water and dissolved mineral nutrients from the soil into the roots by osmosis

c. the conversion of carbon dioxide and water into carbohydrates in the presence of light by green plants

d. the loss of water by evaporation through the leaf surface

e. the movement of water and nutrients within the plant

Complete the following short answer questions.

13. State the respiration formula.

14. State the photosynthesis formula.

Circle the letter that corresponds to the best answer.

15. Cellular respiration is needed for life because ________.

    a. Plants and animals give off carbon monoxide in respiration
    b. Respiration enables a plant to release energy during the breakdown of glucose
    c. Respiration is the process of combining H_2O and CO_2 in the presence of light and chlorophyll to produce glucose and O_2
    d. Respiration is the controlled breakdown of carbon dioxide

16. The direction of movement in translocation is ________.

    a. Up only
    b. Down only
    c. Up and down only
    d. Up, down, and horizontal

17. Which of the following tissues is used in translocation?

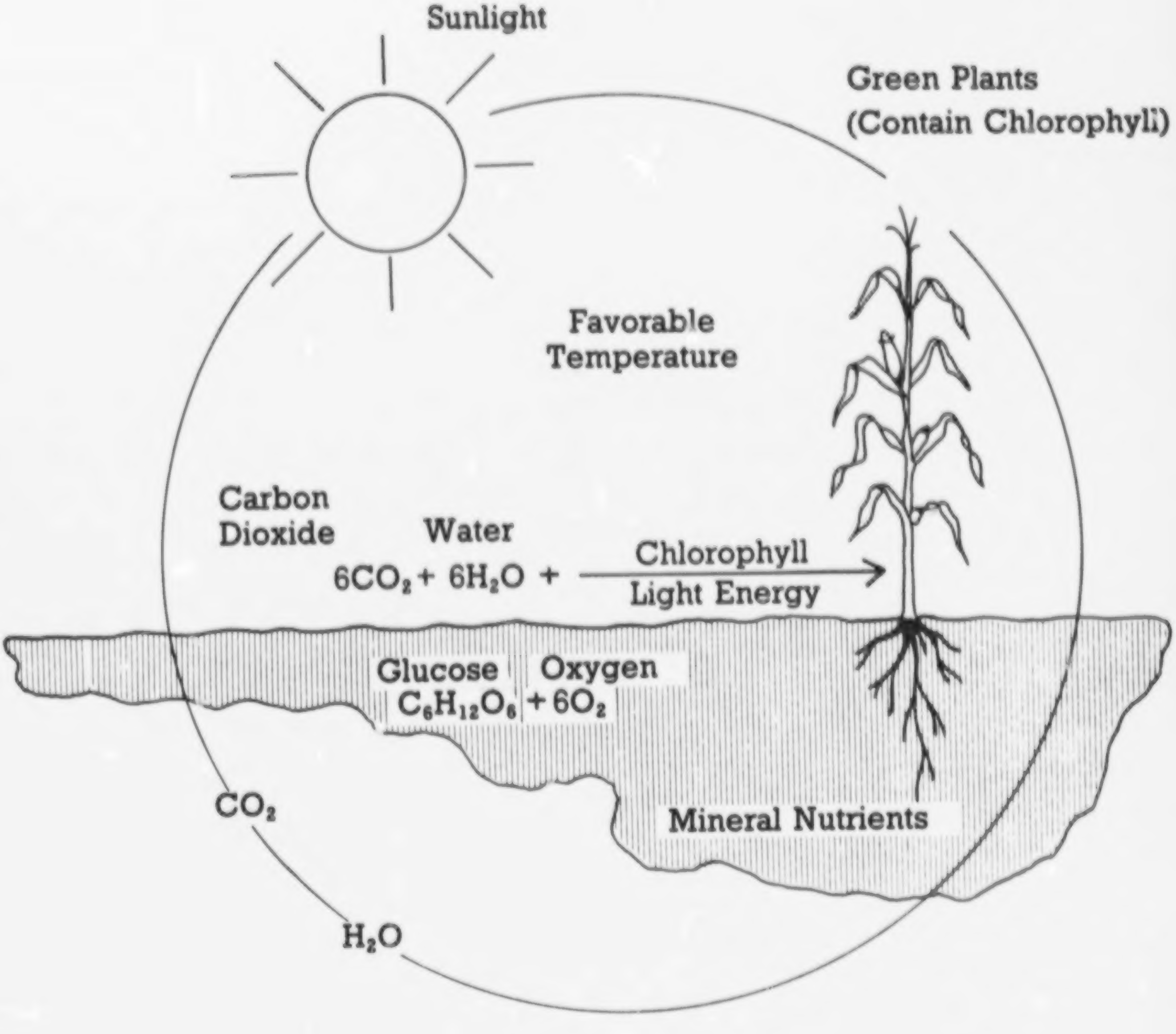
    a. Xylem tissues only
    b. Phloem tissues only
    c. Xylem and phloem tissues
    d. Meristem tissues

18. The rate of transpiration in a plant will ________ when the temperature is increased and the wind velocity is increased.

    a. Decrease
    b. Increase
    c. Have no effect(s)
    d. Result in a constant value

TM 9.1

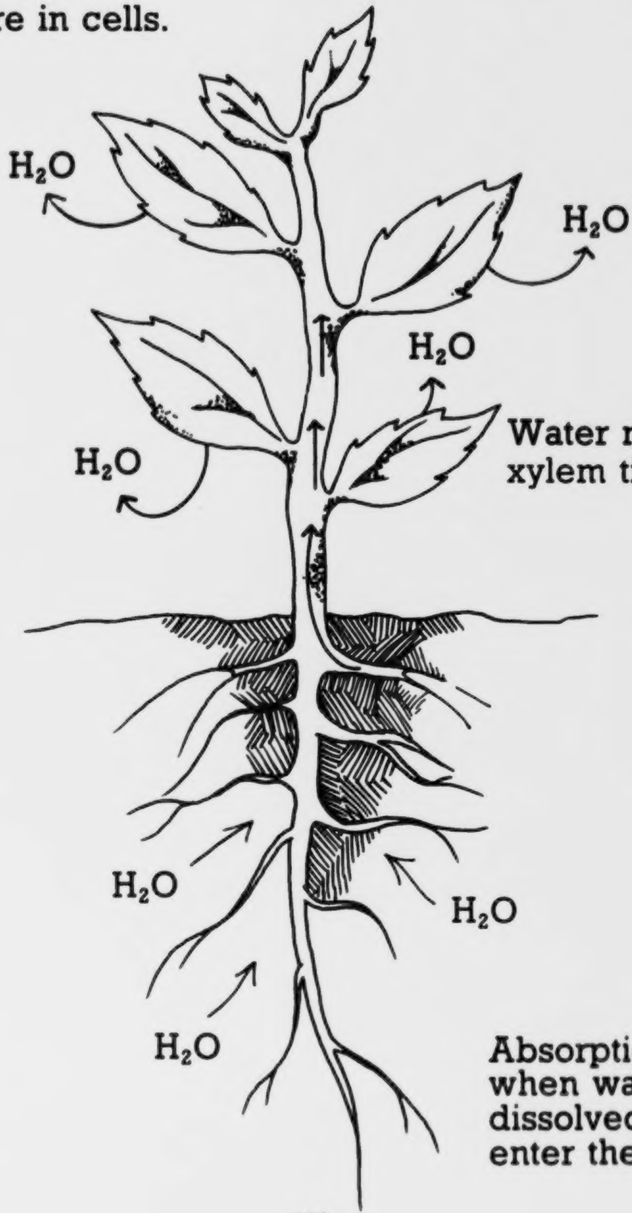
Photosynthesis


Sunlight
Green Plants
(Contain Chlorophyll)
Favorable
Temperature
Carbon
Dioxide
Water
$6CO_2 + 6H_2O +$
Chlorophyll
Light Energy
Glucose
Oxygen
$C_6H_{12}O_6 + 6O_2$
Mineral Nutrients
CO_2
H_2O

Photosynthesis vs. Respiration

	Photosynthesis	**Cellular Respiration**
Energy relationships - stored or released	Stored	Released
Raw materials	CO_2 and H_2O	Glucose and O_2
Function	To convert sun energy into chemical energy	To release energy from glucose for cellular metabolism
End products	O_2 and glucose	CO_2, H_2O, and energy

Absorption and Transpiration


H_2O
H_2O
H_2O
H_2O
H_2O
H_2O
H_2O

Transpiration causes reduced pressure in cells.

Water moves up through the xylem tissues.

Absorption occurs when water and dissolved nutrients enter the root cells.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 10: Environmental Effects on Plant Growth

Objective: The student will be able to describe the environmental effects on plant growth.

Study Questions

1. **What is light intensity and how is it measured?**
2. **What are the effects of light intensity on plant growth?**
3. **How does light duration affect plant growth?**
4. **What is light quality, and how do the different wavelengths affect plant growth?**
5. **How does temperature affect photosynthesis?**
6. **How does the cellular respiration rate react to changes in temperature?**
7. **How does water affect the plant?**
8. **What are the effects of gaseous components of air on plants?**
9. **How does nutrient availability affect plant growth?**

Reference

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

To successfully produce plants, it is important to understand how environmental factors affect plant growth. Upon completing this unit, the student will be able to understand how plant growth is affected by light intensity, light duration, light quality, temperature, water, and air.

C. Assignment

D. Supervised study

E. Discussion

1. Have students define light intensity.

   What is light intensity and how is it measured?

   a) Light intensity is the quantity of light or the brightness of light.
   b) A common measurement of light intensity is the footcandle. One footcandle is the amount of light striking a surface one foot from a standard wax candle.

2. Discuss with students the effects of light and light intensity on plant growth.

   What are the effects of light intensity on plant growth?

   a) Light intensity categories of plants
      1) Low light intensity plants - 500 to 1,250 fc.
      2) Medium light intensity plants - 1,250 to 2,500 fc.
      3) High light intensity plants - more than 2,500 fc.
   b) Plant response
      1) Deficient light intensity
         (a) Photosynthesis occurs at reduced rate
         (b) Longer internodes
         (c) Reduced pigment formation
         (d) Weak stems
         (e) Less leaf area
         (f) No flowering
      2) Adequate light intensity
         (a) Increased photosynthesis
         (b) Increased height
         (c) Thicker stems
         (d) Greater leaf area
         (e) Shorter internodes
         (f) More roots
         (g) Earlier flowering
         (h) More flowers
         (i) Larger flowers
         (j) Increased pigment formation

    3) Too much light intensity
        (a) Decreased photosynthesis
        (b) Increase in temperature resulting in excessive rate of cellular respiration and depletion of food supply
        (c) Reduced pigment formation
        (d) Smaller leaves
        (e) Smaller flowers
        (f) Burning or desiccation of leaf and flower
        (g) Bleached leaves

3. Discuss with students the effects of light duration on plant growth.

How does light duration affect plant growth?

a) Rate of growth directly related to the amount of light received
    1) Photosynthesis occurs only in presence of light.
    2) Plants grow more during long days than short days.
b) Photoperiodism - plant response to light duration
    1) Flower bud initiation
    2) Bulb formation
    3) Tuber formation
    4) Bract coloration
    5) Plantlet formation
c) Plant response to day length (photoperiodic response)
    1) Short-day plants (e.g., poinsettias, chrysanthemums) flower only when day length is shorter than a critical length.
    2) Long-day plants (e.g., tuberous begonias, asters) flower only when day length is longer than a critical length.
    3) Day-neutral plants (e.g., African violets, roses) are not affected by the length of the day.
d) Ways to control the length of the day
    1) Extend the day length by using artificial lights
    2) Shorten the day length by using a black cloth

4. Ask students to define light quality and discuss how light quality affects plant growth.

What is light quality, and how do the different wavelengths affect plant growth?

a) Light quality - the wavelength or color of light
    1) Not all wavelengths can be used by plants for photosynthesis.
    2) Light quality is measured in a unit of length called a nanometer (nm).
b) Wavelengths
    1) Ultraviolet light
        (a) Wavelengths are very short, less than 430 nm.
        (b) Ultraviolet light is invisible.
        (c) High levels of ultraviolet light can reduce photosynthesis and cause sunscald.
        (d) Glass screens out most ultraviolet light and all light shorter than 325 nm.
    2) Visible or white light - preferred for growing plants; wavelength - 390 to 760 nm; Combination of violet, blue, green, yellow, orange, and red light
        (a) Blue light
            (1) Wavelength - 422 to 492 nm
            (2) Plant response when grown with only blue light: shorter, dark in color, hard tissues
            (3) Very high photosynthetic activity
            (4) Very evident phototropism - stem bending toward light coming from one direction
        (b) Green light
            (1) Wavelength - 492 to 535 nm

        - (2) Very low photosynthetic activity
    - (c) Red light
        - (1) Wavelength - 647 to 760 nm
        - (2) Very high photosynthetic activity
        - (3) Plant response when grown with only red light: soft growth, long internodes, seed germination promoted, photoperiodic response in long-day plants
- 3) Far-red light
    - (a) Wavelength - 760 to 780 nm
    - (b) Plant response to far-red light
        - (1) Flowering of short-day plants is promoted.
        - (2) Flowering of long-day plants is inhibited.
- 4) Infrared light
    - (a) Wavelength - 780+ nm
    - (b) Invisible
    - (c) Plant response to infrared light, which affects heat transfer
        - (1) Overheating causes stomata to close, thereby conserving water.
        - (2) Photosynthesis stops.

5. Discuss with students how temperature affects the plant's ability to make food.

How does temperature affect photosynthesis?

- a) Temperature levels that affect photosynthesis
    - 1) Minimum temperature - level below which no photosynthesis occurs
    - 2) Optimum temperature - photosynthesis greatest at this level
    - 3) Maximum temperature - level above which no photosynthesis occurs
- b) Effect on photosynthesis
    - 1) The rate of photosynthesis in many plants increases as the temperature increases until it reaches 95°F (35°C).
    - 2) At temperatures above 95°F, the rate of photosynthesis drops very quickly then stops because enzymes involved in the process are deactivated.
    - 3) Optimum temperature range for photosynthesis in most plants is between 50°F and 75°F (10°C to 24°C).
    - 4) Minimum temperature varies with plant species.
- c) Effect on plant growth
    - 1) Lower than optimum temperature
        - (a) Delays flowering
        - (b) Slower rate of growth
        - (c) May intensify color of leaves and flowers
    - 2) Higher than optimum temperature
        - (a) Promotes earlier and smaller flowers
        - (b) Reduces number of leaves
        - (c) Reduces the diameter of stems
        - (d) Reduces flower color
        - (e) May inhibit or delay flowering

6. Discuss with students how temperature affects the rate of respiration of plants.

How does the cellular respiration rate react to changes in temperature?

- 1) Cellular respiration rate increases as the temperature increases.
- 2) Cellular respiration depletes the food (simple sugar) made during photosynthesis to fuel all cellular metabolism.
- 3) Reducing the temperature to 10°F less than the daytime optimum at night and on cloudy days will slow respiration.
- 4) Reducing the temperature close to freezing or about 34°F (0.5°C) slows down the rate of respiration enough to store plants, cut flowers, fruits, and vegetables for prolonged periods without deterioration in quality.

7. Discuss with students how water affects plant growth.

How does water affect plant growth?

- a) Maintains turgidity so that stomata are open and CO_2 can enter the leaf
    - 1) Plants wilt when there is too little water.
    - 2) When rising temperatures cause the transpiration rate to exceed the amount of water the plant can absorb, the plant wilts.
- b) Transports dissolved nutrients
    - 1) Nutrients are water soluble.
    - 2) Dissolved nutrients found in soil enter the plant as water is absorbed by root hairs.
    - 3) Dissolved nutrients are translocated as water moves within the plant.

8. Ask students to list the gaseous components of the air. Discuss the effects of gaseous components of air on plant growth.

What are the effects of gaseous components of air on plants?

- a) Gaseous components essential for plant growth
    - 1) Carbon dioxide
        - (a) Carbon dioxide is needed for photosynthesis.
        - (b) Although generally found in adequate amounts in the air, carbon dioxide is a limiting factor for plant growth in greenhouses.
        - (c) Plant growth is promoted and flowering is hastened if CO_2 levels are increased in greenhouses.
            - (1) Needed only during the daytime in fall, winter, and spring when greenhouse fans are off
            - (2) Can be increased by using a CO_2 generator
    - 2) Oxygen
        - (a) Generally found in adequate quantities in the air for plant growth
        - (b) Needed for respiration
    - 3) Water vapors
        - (a) Optimum levels of relative humidity for plant growth is between 40 and 80 percent.
        - (b) Higher relative humidity of 80 to 100 percent can promote fungal disease. This is a problem especially in the winter.
        - (c) Low relative humidity can hinder plant growth because of increased transpiration. Low humidity is seldom a problem except around newly taken cuttings or transplanted seedlings.
            - (1) Shorter plants
            - (2) Less new shoot and leaf growth
            - (3) Smaller flowers
            - (4) Stiff, upright stems
        - (d) Transpiration rate is decreased by increasing relative humidity.
        - (e) There are several ways to increase relative humidity.
            - (1) Water walks and underneath benches.
            - (2) Use humidifiers.
- b) Air pollutants detrimental to plant growth
    - 1) Sulfur dioxide
    - 2) Ethylene
    - 3) Fluoride
    - 4) Chlorine
    - 5) Ammonia
    - 6) Pentachlorophenol fumes
    - 7) Creosote fumes
    - 8) Nitrogen dioxide
    - 9) Peroxyacetyl nitrate (PAN)
    - 10) Ozone

NOTE: Ethylene is most frequently encountered in greenhouses with unit heaters that are not furnished with adequate fresh air intake and are not properly vented.

9. Discuss some of the symptoms of nutrient deficiency in plants. Lesson 18 provides further discussion on plant nutrition.

How does nutrient availability affect plant growth?

a) Plants supplied with adequate levels of minerals will grow at an optimum rate.
b) Plant growth can be reduced by limiting the minerals available to plants.
c) Some symptoms of insufficient nutrition in plants are stunting, yellowing of leaves, and reduced flower yield.

F. Other activity

Start four plants, such as tomato, from seed. Expose each plant to only one of the following conditions: complete darkness, sunlight, fluorescent light, and incandescent light. Record the growth rate and appearance of each plant. Compare the results of the plants' growth under the different lighting conditions. For best results, grow these plants for at least six weeks.

G. Conclusion

Environmental factors which directly influence growth of greenhouse floriculture crops include the following: light, temperature, moisture, gaseous components of air, and mineral nutrients.

H. Competency

Describe the environmental effects on plant growth.

I. Answers to Evaluation

1. c
2. a
3. c
4. b
5. c
6. a
7. d
8. b
9. b
10. c
11. a
12. b
13. e
14. d
15. f
16. c
17. a

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ________________

Lesson 10: Environmental Effects on Plant Growth Date ________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Light intensity is measured in units called _________.

   a. Nanometers
   b. Millimicrons
   c. Footcandles
   d. Degrees

2. The cellular respiration rate _________ as the temperature _________.

   a. Increases, increases
   b. Increases, decreases
   c. Decreases, increases
   d. Stays the same, increases

3. Light intensity can be reduced from mid-spring to early fall through the use of _________.

   a. High intensity discharge lamps
   b. A black cloth
   c. A shading compound
   d. An oil base paint

4. The optimum temperature range for photosynthesis in most plants to occur is _________.

   a. 33°F to 50°F
   b. 50°F to 75°F
   c. 75°F to 95°F
   d. Above 95°F

5. At relatively low temperatures, photosynthesis _________ as the temperature _________.

   a. Decreases, increases
   b. Increases, decreases
   c. Increases, increases
   d. Stays the same, increases

6. As the temperature increases the rate of transpiration _________.

   a. Increases
   b. Decreases
   c. Stays the same
   d. Has no effect

7. The major gaseous components of the atmosphere are _________.

   a. Oxygen, carbon monoxide, nitrogen
   b. Oxygen, carbon dioxide, potassium
   c. Oxygen, carbon monoxide, nitrogen
   d. Oxygen, carbon dioxide, nitrogen

8. The transpiration rate can be reduced by ________ the relative humidity.

  a. Decreasing
  b. Increasing
  c. No effect on each other
  d. Not changing

9. Plants make their greatest amount of growth during ________.

  a. Short days and long nights
  b. Long days and short nights
  c. Long days and long nights
  d. Short days and short nights

10. Plants grown in ____________ light tend to have long internodes and soft growth.

  a. Ultraviolet
  b. Blue
  c. Red
  d. Green

11. Poinsettias switch from vegetative to reproductive growth when the _______.

  a. Nights become longer and the days become shorter
  b. Nights become longer and the days become longer
  c. Days and nights are the same length
  d. Days become longer and the nights become shorter

Match the terms with the definitions:

____12. light intensity

____13. light duration

____14. light quality

____15. photosynthesis

____16. cellular respiration

____17. transpiration

a. the loss of water from the leaves

b. the brightness or quantity of light

c. the controlled breaking down of glucose resulting in plant growth

d. the length of wavelengths of light

e. the length of exposure to light

f. the production of glucose when carbon dioxide, water, and oxygen are in the presence of light and chlorophyll

g. the absorption of water by leaves

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 11: Growth Regulation

Objective: The student will be able to identify the effects that pruning and chemical growth regulators have on plant development.

Study Questions

1. **How can plant growth be regulated?**
2. **What is pruning, and how does it control plant growth?**
3. **How are chemicals used to regulate plant growth?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Master
    a) TM 11.1: Pruning to Control Plant Growth
3. Job Sheet
    a) JS 11.1: Effect of Indolebutyric Acid on Herbaceous Stem Cuttings

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 11: Growth Regulation

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

Plant production can be affected by the use of growth regulators. They can improve plant quality, reduce production time, reduce production cost, stimulate or retard growth, induce rooting, and increase branching. It is important to understand how growth regulators affect plant growth.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss how plant growth can be regulated. Manipulating the environment is a cheap and effective way to control plant growth. Since environmental effects on plant growth were discussed in lesson 10, refer to that lesson for additional information.

How can plant growth be regulated?

a) Controlling the environment
b) Pruning
c) Applying chemicals

2. Discuss how pruning controls plant growth. Use TM 11.1.

How does pruning control plant growth?

a) Primarily the way to produce a smaller bushier plant
b) Control plant growth
    1) Shape
    2) Size
    3) Direction of growth
    4) Flowering
    5) Number of plant stems produced
c) Remove dense growth
    1) Allows light and air in
    2) Shapes plant
    3) Removes damaged and diseased tissues
    4) Encourages flowering
    5) Creates special effects and beauty
    6) Removes broken roots during transplanting
d) Pruning concepts
    1) Labor intensive
    2) Time-consuming
    3) Expensive
e) Basic techniques used in the greenhouse
    1) Heading back - shortens branch, but does not remove it completely (e.g., rose bushes)

2) Pinching
   - (a) Terminal bud removal
   - (b) Removal of apical dominance forces axillary buds to grow, resulting in a multi-branched plant (e.g., multi-branched poinsettia).

3) Disbudding
   - (a) Removal of axillary flower buds
   - (b) Causes terminal flower bud to develop producing one large flower (e.g., "football" mum).

3. Have students list the five categories of chemical growth regulators. Discuss each of the five categories and how each affects plant growth. Have students complete JS 11.1.

What chemicals are used to regulate plant growth?

a) Auxins
   - 1) Promote plant growth by encouraging cell division and cell enlargement
   - 2) Promote root formation on cuttings

b) Gibberellins
   - 1) Promote plant growth by encouraging cell division and cell enlargement
   - 2) Initiate flower development
   - 3) Replace cold treatment
     - (a) Break seed and bud dormancy
     - (b) Promote uniform development during forcing

c) Cytokinins
   - 1) Enhance cell division
   - 2) Are required for plant tissue culture

d) Ethylene gas
   - 1) Retards height
   - 2) Promotes flowering
   - 3) Promotes color formation in fruit
   - 4) Ripens fruit

e) Growth retardants
   - 1) Reduce cell division and cell elongation
     - (a) Shorten the length of branches
     - (b) Increase chlorophyll concentration
     - (c) Promote early flower formation
   - 2) Chemically pinch plants - encourages lateral branching

F. Other activities

1. Set up a display of different chemical growth regulators.

2. Treat identical plants with various chemical growth regulators. Compare each plant's response with an untreated plant receiving the same environmental conditions.

G. Conclusion

Plant growth may be regulated in three main ways: by mechanical pruning, by using chemicals, and/or by manipulating the greenhouse environmental factors of light, temperature, moisture, CO_2, and mineral nutrients. In addition, plant growth may be controlled genetically by appropriate cultivar selection.

H. Competency

Identify the effects that pruning and chemical growth regulators have on plant development.

I. Answers to Evaluation

1. e
2. b
3. d
4. a
5. f
6. g
7. c
8. d
9. d
10. a

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Name ____________________

Lesson 11: Growth Regulation

Date ____________________

EVALUATION

Match the terms with the correct definition.

____ 1. pinching

____ 2. disbudding

____ 3. auxin

____ 4. gibberellin

____ 5. cytokinin

____ 6. ethylene

____ 7. inhibitors

a. a plant hormone that causes cell enlargement and initiates flower development

b. removal of axillary flower buds

c. a class of chemical compounds which reduces cell division and cell elongation and also encourages lateral branching

d. a plant hormone that promotes root formation

e. removal of a plant's terminal tip

f. a group of chemical substances that enhances cell division

g. a substance that acts as a height retardant and hastens the ripening of fruits

Circle the letter that corresponds to the best answer.

8. Pruning controls plant growth by directing ________.

   a. Shape
   b. Size
   c. Growth
   d. All of the above

9. Which of the following growth regulators can be used to replace cold treatment?

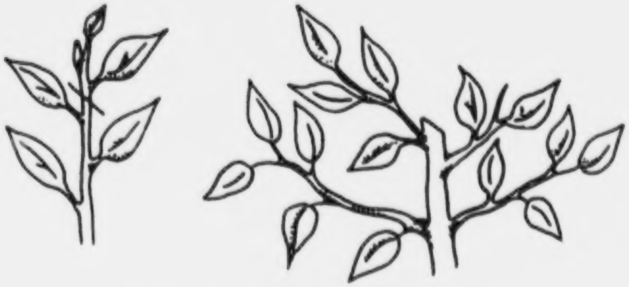
   a. Auxin
   b. Cytokinin
   c. Ethylene
   d. Gibberellin

10. Which of the following growth regulators can be used as a way to chemically pinch plants?

   a. Growth retardants
   b. Cytokinin
   c. Gibberellin
   d. Ethylene

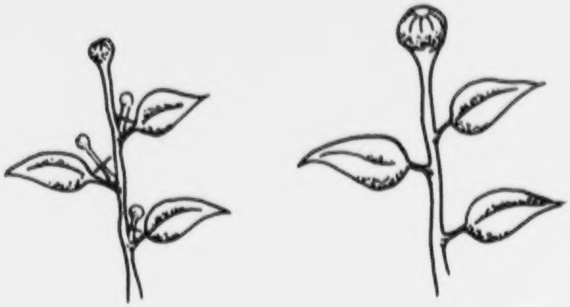
Pruning to Control Plant Growth

Pinching



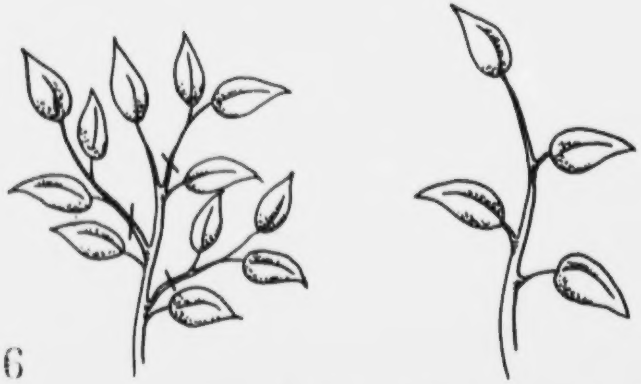
Promotes Branching

Disbudding

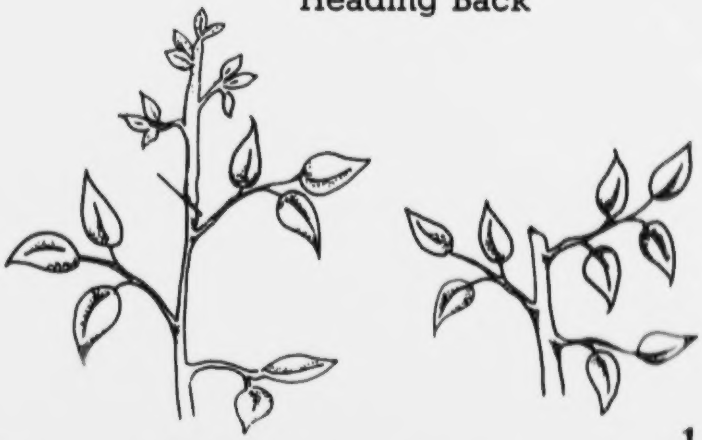


Develops One Large Flower Per Stem

Controlling Plant Shape



Heading Back



Direct Plant Shape, Growth Direction and Productivity of Plants

TM 11.1

JS 11.1: Effect of Indolebutyric Acid on Herbaceous Stem Cuttings

Objective: Upon completion of this job sheet, the student will be able to identify the effect of indolebutyric acid on herbaceous stem cuttings.

Materials and supplies needed:

1. Herbaceous plant - Instructor will determine the type of plant.
2. Knife or other propagation tool
3. Rooting hormone (preferably one containing indolebutyric acid)
4. Propagation bed with appropriate growing medium
5. Plant identification markers

Procedure:

1. Using the knife, remove four inches from the terminal tip of ten plants. Use plants of the same species.

2. Apply the rooting hormone to five cuttings.

3. Place the cuttings in the propagation bed and use markers to indicate which have been treated with rooting hormone.

4. Provide adequate water and light for selected plant. (Check with your instructor.)

5. Check cuttings daily and record when each cutting roots.

Cutting No.	Days: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 12: Floriculture Plant Identification

Objective: The student will be able to identify plants important to the Missouri floriculture industry.

Study Questions

1. **What are 21 important bedding plants?**
2. **What are 30 important house plants?**
3. **What are 15 important container-grown flowering plants?**
4. **What are 20 important cut flower/foliage plants?**
5. **What are 12 important perennial plants?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Rothenberger, Barbara. Floriculture Plant Identification. Slide Set. University of Missouri-Columbia: Instructional Materials Laboratory.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 12: Floriculture Plant Identification

TEACHING PROCEDURES

A. Review

Review previous lessons.

B. Motivation

It is important to be able to identify plants important to the Missouri floriculture industry. These plants are categorized as follows: bedding plants, house plants, container-grown flowering plants, cut flower/foliage plants, and perennial plants. In order to provide optimal cultural conditions for each major floriculture crop, it is necessary to correctly recognize and identify each type of plant.

C. Assignment

D. Supervised study

E. Discussion

1. Have students identify 21 important bedding plants.

What are 21 important bedding plants?

Common Name	Scientific Name
Ageratum	Ageratum mexicanum
Cabbage	Brassica oleracea capitata
Celosia or Cockscomb	Celosia cristata
Coleus	Coleus x hybridus
Dusty Miller	Senecio cineraria
Geranium	Pelargonium x hortorum
Impatiens or Sultana	Impatiens hybrid
Ivy Geranium	Pelargonium peltatum
Marigold	Tagetes sp.
Nasturtium	Tropaeolum majus
Pansy	Viola x Wittrockiana
Pepper, Green	Capsicum fruitescens
Petunia	Petunia x hybrida
Rose Moss	Portulaca grandiflora
Salvia	Salvia splendens
Sweet Alyssum	Lobularia maritima
Tomato	Lycopersicum esculentum
Verbena	Verbena x hybrida
Vinca	Catharanthus roseus
Wax Begonia	Begonia x semperflorens
Zinnia	Zinnia elegans

2. Have students identify 30 important house plants.

What are 30 important house plants?

Common Name	Scientific Name
African Violet	Saintpaulia ionantha
Aluminum Plant	Pilea cadierei
Boston Fern	Nephrolepsis exaltata 'Bostoniensis'
Burro's Tail	Sedum morganianum
Caladium	Caladium hortulanum
Corn Plant Dracaena	Dracaena fragrans massangeana
Croton	Codiaeum variegatum pictum
Crown of Thorns	Euphorbia splendens
Dwarf Schefflera	Schefflera arbicola
Emerald Ripple Peperomia	Peperomia caperata 'Emerald Ripple'
English Ivy	Hedera helix
Fuchsia	Fuchsia hybrida
German Ivy	Senecio mikanioides
Gold-Edged Snake Plant or Mother-in-Law Tongue	Sansevieria trifasciata 'Laurentii'
Golden Pothos or Devil's Ivy	Scindapsus aureus
Heartleaf Philodendron	Philodendron scandens oxycardium
India-Rubber Plant	Ficus elastica 'Decora'
Jade Plant	Crassula argentea
Medicine Plant	Aloe vera
Norfolk Island Pine	Araucaria heterophylla
Polka Dot Plant	Hypoestes phyllostachya
Prayer Plant	Maranta leuconeura 'Kerchoveana'
Spider Plant	Chlorophytum commosum
Spotted Dumbcane	Dieffenbachia maculata
Sprengeri "Fern"	Asparagus densiflorus 'Sprengeri'
Strawberry Begonia	Saxifraga sarmentosa
Umbrella Plant	Brassaia actinophylla
Variegated Peperomia	Peperomia obtusifolia 'Variegata'
Wandering Jew	Zebrina pendula
Wax Plant	Hoya carnosa

3. Have students identify 15 important container-grown flowering plants.

What are 15 important container-grown flowering plants?

Common Name	Scientific Name
Amaryllis	Hippeastrum hybrid
Azalea	Rhododendron sp.
Calceolaria or Pocketbook Plant	Calceolaria herbeohybrida
Cyclamen	Cyclamen persicum
Easter Lily	Lilium longiflorum
Exacum or Persian Violet	Exacum affine
Florist's Chrysanthemum or Pot Mum	Chrysanthemum morifolium
Florist's Cineraria	Senecio x hybridus
Gloxinia	Sinningia speciosa
Hibiscus	Hibiscus rosa-sinensis
Hydrangea	Hydrangea macrophylla
Kalanchoe	Kalanchoe blossfeldiana
Poinsettia	Euphorbia pulcherrima

Primrose or Primula	Primlua sp.
Rieger Begonia	Begonia hiemalis

4. Have students identify 20 important cut flower/foliage plants.

What are 20 important cut flower/foliage plants?

Common Names	Scientific Names
Bird of Paradise	Strelitzia reginae
Carnation	Dianthus caryophyllus
Cattleya Orchid	Hybrid Cattleya
Cymbidium Orchid	Cymbidium
Daffodil	Narcissus pseudo-narcissus
Emerald and Jade	Chamaedorea sp.
Garden Gladiolus	Gladiolus grandiflorus
Gardenia	Gardenia jasminoides fortuniana
Gerbera or Transvaal Daisy	Gerbera jamesonii
Huckleberry	Vaccinium ovatum
Hybird Tea Rose	Rosa hybrida, Class Hybrid Tea
Salal or Lemon Leaf	Gaultheria shallon
Silver Dollar Gum or Eucalyptus	Eucalyptus polyanthemos
Snapdragon	Antirrhinum majus
Statice	Limonium sinuatum
Stephanotis	Stephanotis floribunda
Stock	Matthiola incana
Strawflower	Helichrysum bracteatum
Tulip	Tulipa sp.

5. Have students identify 12 important perennial plants.

What are 12 important perennial plants?

Common Name	Scientific Name
Ajuga or Bugle Weed	Ajuga reptans
Cannas	Canna indica
Clematis	Clematic sp.
Coreopsis or Tickseed	Coreopsis grandieflorium
Daylily	Hemerocallis hybrida
Dragon's Blood Sedum	Sedum spurium coccineum 'Dragon's Blood'
Gypsophila or Baby's Breath	Gypsophila paniculata
Hosta or Plantain Lily	Hosta sp.
Iris	Iris x germanica
Peony	Paeonia lactiflora
Rudbeckia Daisy or Black Eyed Susan	Rudbeckia fulgida
Shasta Daisy	Chrysanthemum superbum

F. Other activities

1. Plan a field trip to a botanical garden, a retail florist, a wholesale greenhouse, and/or a retail greenhouse to view examples of the plants included in this lesson. Ask students to take notes about their field observations on these plants, particularly noting any distinguishing characteristics or special cultural practices. Require students to turn in their notes for grading.

2. Plan a field trip to a flower show and/or plant exhibition for the purpose of viewing examples of the plants included in this lesson.

3. Invite guest speakers to give presentations to the class. Sources of guest speakers might be garden clubs or special interest plant clubs (e.g., African Violet Society, Rose Society, Daylily Club). Ask students to take notes and turn them in for grading.

4. Ask students to compile floriculture plant identification scrapbooks that include pictures and accompanying descriptions of the plants listed in this lesson. Seed catalogs and gardening magazines might serve as two sources of pictures and descriptions. Have students turn in the scrapbooks for a grade.

G. Conclusion

The 98 plants included in this lesson are important to the Missouri floriculture industry. Only by being properly identified can plants be provided with optimal cultural care.

H. Competency

Identify plants that are important to the Missouri floriculture industry.

I. Answers to Evaluation

Since this is a lab practical, answers will need to be determined by the instructor.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 12: Floriculture Plant Identification

EVALUATION

The evaluation will be a lab practical. Choose examples of living plants (as many as possible) and examples from the slide set. Ask students to identify the plants one by one. Ask students to provide the common name of each plant and its category according to primary use (i.e., bedding plants, house plants, container-grown flowering plants, cut flower/foliage plants, or perennial plants).

Optional: Give students a list with the scientific names of the 98 plants. Ask students to match the correct scientific name with examples on the lab practical.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 13: Sexual Plant Propagation

Objective: The student will be able to start plants from seeds.

Study Questions

1. **What are the kinds of plant propagation?**
2. **What are the requirements for seed germination?**
3. **What are the steps in seed germination of a dicot?**
4. **What are the steps in seed germination of a monocot?**
5. **What is dormancy and how is it overcome?**
6. **What are the steps required when sowing and watering seeds in a seed flat?**
7. **How should seedlings be cared for after germination?**
8. **When are seedlings transplanted?**
9. **How are seedlings transplanted?**
10. **What disease control measures are used when germinating seeds?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Masters
    a) TM 13.1: Steps in Seed Germination of a Dicot
    b) TM 13.2: Steps in Seed Germination of a Monocot
3. Assignment Sheet
    a) AS 13.1: Seed Packet Information
4. Job Sheets
    a) JS 13.1: Sowing Seed
    b) JS 13.2: Transplanting Seedlings

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 13: Sexual Plant Propagation

TEACHING PROCEDURES

A. Review

Review Lesson 8: Plant Parts, Structures, and Functions.

B. Motivation

The successful production of plants from seeds is dependent upon understanding the principles and techniques of sexual plant propagation. Upon completing this lesson, the student will be able to successfully propagate plants from seed

C. Assignment

D. Supervised study

E. Discussion

1. Ask students to define plant propagation. Write the definition on the board. Discuss the difference between sexual and asexual plant propagation.

What are the kinds of plant propagation?

a) Sexual plant propagation is the use of seeds for the production of new plants.
b) Asexual plant propagation is the reproduction of plants by using a vegetative part of the plant.
    1) Layering
    2) Division
    3) Cuttings
    4) Grafting
    5) Budding
    6) Tissue culture or micropropagation

2. Ask students to list the requirements for seed germination. Have students complete AS 13.1.

What are the requirements for seed germination?

a) Germination medium
    1) Characteristics
        (a) Loose
        (b) Well-drained
        (c) Fine-textured
        (d) Sterile
    2) Types of germination media
        (a) Commercial mixes
            (1) Jiffy Mix®
            (2) Redi-Earth®
            (3) Pro-Mix®
        (b) Home-mixed germination media
            (1) Peat-vermiculite-perlite 2:1:1
            (2) Peat-vermiculite 1:1
            (3) Vermiculite
            (4) Milled sphagnum moss

- b) Moisture
  - 1) Germination begins when the seed absorbs moisture.
  - 2) Germination medium should be moist.
  - 3) After sowing seeds, mist with fine spray.
  - 4) Cover flat; no further water should be required until germination occurs.
- c) Favorable temperatures
  - 1) General germination temperature range is 68°-86°F (20°-30°C).
  - 2) Seeds germinate at different temperatures.
  - 3) Heating cables can be used to regulate soil temperature.
  - 4) Soil temperature should remain constant.
- d) Oxygen
  - 1) Seeds require oxygen for respiration.
  - 2) As seeds germinate, oxygen demand increases.
  - 3) Germination medium and water supply affect oxygen supply.
- e) Presence or absence of light
  - 1) Some seeds require light to germinate; do not cover seeds.
  - 2) Some seeds require no light to germinate; cover seeds with medium or place in a darkened area.
- f) Selection of quality seed
  - 1) Viable seed - ability to germinate and grow
  - 2) Free of insects
  - 3) Free of disease
  - 4) Free of weed seeds
  - 5) Free of broken seeds
- g) Special treatment to overcome dormancy

3. Ask the students to list the steps in seed germination of a dicot. Use TM 13.1.

What are the steps in seed germination of a dicot?

- a) Seed swells as moisture is absorbed.
- b) The seed coat splits.
- c) The radicle emerges and grows down.
- d) The hypocotyl elongates, forms an arch, and pulls the cotyledons upward.
- e) When the hypocotyl reaches light, elongation ceases. The hypocotyl straightens up and pulls the cotyledons out of the soil.
- f) The cotyledons open up, turn green, and provide food until the true leaves develop.
- g) The first true leaves unroll or unfold from the epicotyl, exposing the growth bud. The plant begins to grow.
- h) The cotyledons die, dry up, and fall off.

4. Ask students to list the steps in monocot seed germination. Discuss how it is different from dicot seed germination. Use TM 13.2.

What are the steps in seed germination of a monocot?

- a) Seed swells as moisture is absorbed
- b) Seed coat ruptures.
- c) Radicle grows down.
- d) First internode and epicotyl grow up.
- e) After the epicotyl emerges, new leaves form and food production starts.
- f) The new root system grows just beneath the soil above the first internode.

5. Discuss with students how to overcome seed dormancy.

What is dormancy and how is it overcome?

- a) Dormancy - resting stage of the seed that prevents the seed from germinating until environmental conditions are favorable

b) Methods to overcome
   1) Scarification - scratching the seed coat to allow moisture to penetrate a hard seed coat
      (a) Rub the seed over coarse sandpaper.
      (b) Nick the seed coat.
      (c) Soak the seed in sulfuric acid.
   2) Stratification - exposing the seed to cold, moist conditions (40°F [4°C] for 12 to 14 weeks)

NOTE: Read the seed packet or catalog to determine if seed dormancy is present.

6. Ask students to list the steps required when sowing and watering seeds in seed flats. Have students complete JS 13.1.

What are the steps required when sowing and watering seeds in a seed flat?

a) Fill the container to 3/4 inch from the top of the container with moist germination mixture. Allow for adequate drainage.
b) Level and firm the germination medium.
c) Make shallow rows 1 to 2 inches apart. Different types of seeds can be sown in the same flat if placed in rows.
d) Space seeds uniformly and thinly in rows. Gently tap seed package to space small round seeds. Label each row or flat with plant type, variety, and date of planting.
e) Cover the seeds with dry germination medium, vermiculite, or milled sphagnum moss (general rule of thumb: twice the diameter of the seed). Very small seeds do not need to be covered.
f) Moisten the surface with a fine mist or place in a shallow pan of warm water and let the seed flat take up water from below until the surface is moist.
g) Cover the flat with clear plastic or glass. An uncovered flat should be placed in a propagation bed.
h) Place the seedling flat in a warm location for best germination (general temperature range 65°-75°F [18°-24°C]).
i) Watch daily for germination, lack of water, excess water, or disease.

7. Discuss with students the care of seedlings after germination.

How should seedlings be cared for after germination?

a) Remove the cover after seeds have germinated.
b) Move the container to a location that receives bright light.
c) Reduce growing temperature 10°F below germination temperature.
d) Keep flats moist at all times, but not soggy.
e) Allow drying between watering, but do not allow seedlings to wilt at any time.
f) Fertilize promptly and regularly.
   1) Apply one-fourth the recommended strength a few days after germination.
   2) Fertilize twice a week with diluted solution (about 150 ppm nitrogen).
   3) Young seedlings are easily damaged by too much fertilizer.
   4) A water soluble fertilizer should be used.

8. Ask students when seedlings are ready to be transplanted.

When are seedlings transplanted?

a) Seedlings should be transplanted as soon as they have developed at least one set of true leaves that are large enough to handle.
b) If seedlings are not transplanted promptly, they become overcrowded and spindly, and the quality of the plant is greatly reduced.

9. Describe to students how seedlings are transplanted. Have students complete JS 13.2.

How are seedlings transplanted?

- a) Carefully dig up the small plants with a knife, spatula, or label.
  - 1) Avoid excess loss of seedlings by digging up only small groups of seedlings at one time.
  - 2) Exposing the roots to air causes them to dry out quickly.
- b) Gently separate seedlings and pick out individual plants to be transplanted.
  - 1) If seedlings are difficult to separate, divide them into small groups.
  - 2) Separate them into individual plants.
  - 3) Avoid tearing the roots.
  - 4) Handle seedlings by their leaves.
- c) Transplant seedlings into individual pots or packs filled with moist growing medium.
  - 1) Commercial mix
  - 2) Home-mix (e.g., 2:1:1 ratio of peat-vermiculite-perlite)
- d) Poke a hole in the center of the medium with a dibble or a pencil.
- e) Insert seedlings slightly deeper than they were growing in the seedling flats.
- f) Firm the soil and water gently to settle it.
- g) Place newly transplanted seedlings in a shaded area or cover with a shade cloth for a few days.
- h) Continue to water and fertilize as recommended.

10. Discuss with students ways to control diseases when germinating seeds.

What disease control measures are used when germinating seeds?

- a) Use a soilless mix or sterilized soil and containers.
  - 1) Ways to sterilize soil (Commercial mixes are already sterile.)
    - (a) Heating soil to 180°F (82°C) for 30 minutes
      - (1) Steam
      - (2) Electricity
    - (b) Chemicals
  - 2) How to sterilize containers
    - (a) Disinfect with a solution of one part chlorine bleach and ten parts water or a commercial disinfectant such as Physan 20®.
    - (b) Allow items to dry before filling with soil.
- b) Watch seedlings closely for plant diseases such as damping-off.
  - 1) To battle a limited infection of seedlings, dig out and discard infected plants and soil.
  - 2) In case of a wider spread of infection, drench the entire soil area with a fungicide.
  - 3) Improve air circulation.
  - 4) Allow soil to dry out slightly between waterings.

F. Other activities

1. Demonstrate how to sow seeds, label flats, care for seedlings, and transplant seedlings.

2. Have students sow both monocot and dicot seeds. Have them write down their observations when the seeds start to come up.

3. Have students plant ten morning-glory seeds. Have them scarify five of the seeds before planting. Have students write down their observations when the seeds start to come up.

4. View one of the following films available from the Academic Support Center Film Library, 505 East Stewart Road, Columbia, MO 65201.

   - a) Seed Germination. 16 mm film. 15 min.
   - b) Growth of Seeds. 16 mm film. 14 min.

5. View Bedding Plant Production, a sound filmstrip available from Vocational Education Productions, California Polytechnical State University, San Luis Obispo, CA, 1988.

G. Conclusion

Some seeds will not germinate until certain environmental conditions are met. After germinating in the seed flat, the seedlings are usually transplanted into larger individual containers for growing.

H. Competency

Start plants from seeds.

I. Answers to Evaluation

1. a
2. c
3. a
4. c
5. c
6. c
7. b
8. c
9. d
10. a
11. 3
12. 8
13. 5
14. 1
15. 7
16. 2
17. 6
18. 4

J. Answers to AS 13.1 - The instructor will need to determine if answers are appropriate.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ________________

Lesson 13: Sexual Plant Propagation Date ________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The reproduction of plants using a vegetative part of the plant is a type of ____________ plant propagation.

   a. Asexual
   b. Bisexual
   c. Sexual
   d. Unisexual

2. The germination medium in which to sow seeds must be _________.

   a. Well-vented
   b. Course-textured
   c. Sterile
   d. Fertile

3. The germination temperature should _________.

   a. Remain constant
   b. Be cooler during the day
   c. Be warmer during the day
   d. None of the above

4. Rubbing the seed coat with coarse sandpaper is one method of _______.

   a. Sterilization
   b. Stratification
   c. Scarification
   d. Germination

5. Which of the following should be found on a label for a seed flat?

   a. Date sown and selling date
   b. Variety name and germination percentage
   c. Plant type, variety, and date sown
   d. Planter's name and date sown

6. Seedlings should be fertilized _________.

   a. Daily at full strength
   b. Daily at half recommended strength
   c. Twice a week with diluted solution
   d. Every two weeks at half recommended strength

7. Seedlings should be transplanted _________.

   a. When the second set of true leaves are developed
   b. When the first set of true leaves are large enough to handle
   c. When the cotyledon leaves are fully developed
   d. When the cotyledons are large enough to handle

8. Seedlings should be handled by the _________ and inserted slightly deeper than they were grown in the seedling flats.

    a. Roots
    b. Stems
    c. Leaves
    d. Cotyledons

9. Containers can be sterilized with _________.

    a. Vinegar
    b. Full strength chlorine bleach
    c. A solution of one part bleach and one part water
    d. A solution of one part chlorine bleach and ten parts water

10. A fungal disease that seedlings are susceptible to is _________.

    a. Damping-off
    b. Rotting-off
    c. Mildew
    d. Root rot

Indicate the correct order in the steps of seed germination of a dicot by placing numerals 1 - 8 in the correct sequence.

_____11. The radicle emerges and grows down.

_____12. The cotyledons die, dry up, and fall off.

_____13. When the hypocotyl reaches light, it straightens up and pulls the cotyledons out of the soil.

_____14. Seed swells as moisture is absorbed.

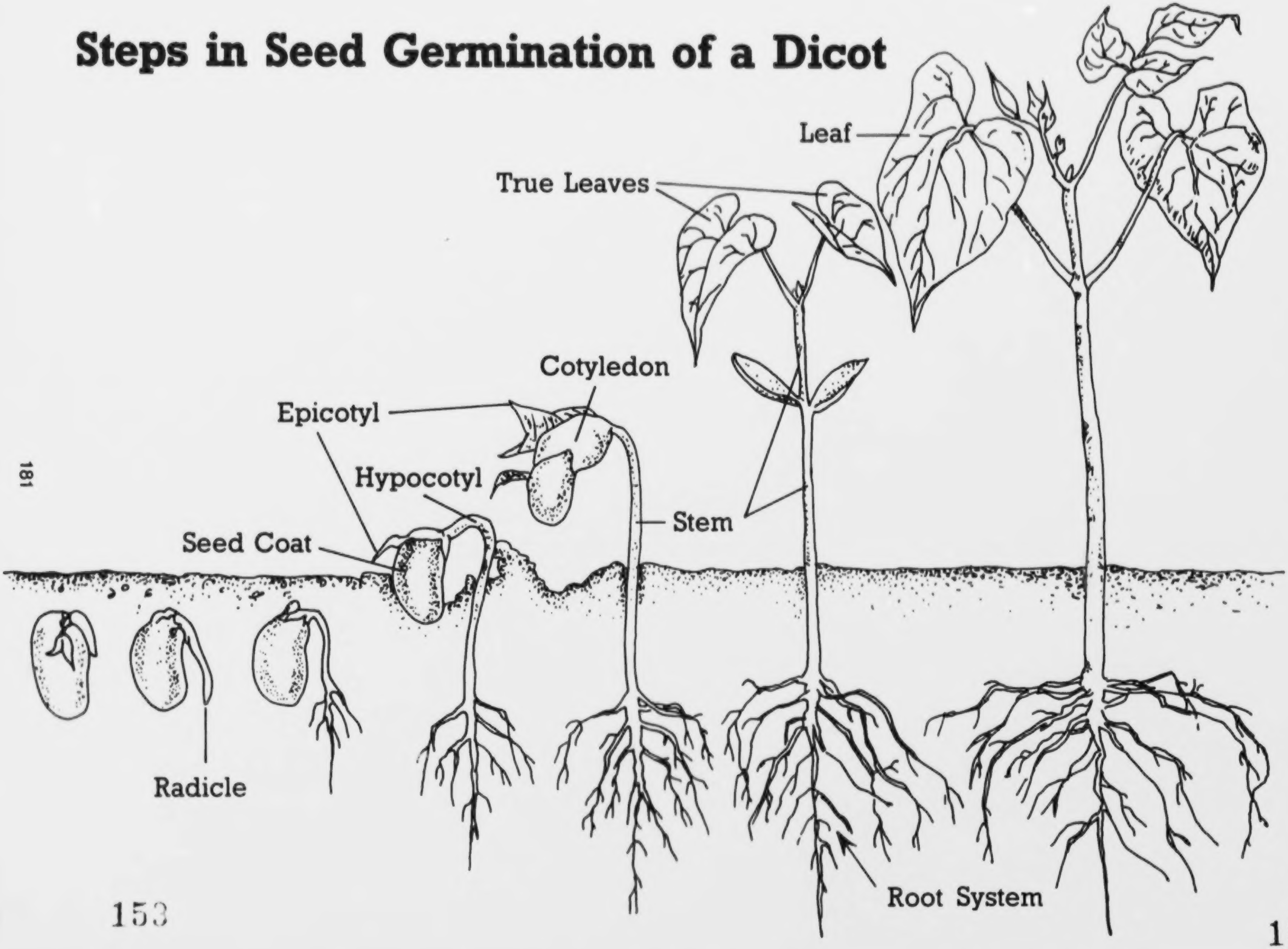
_____15. The first true leaves unroll or unfold from the epicotyl, exposing the growth bud; the plant begins to grow.

_____16. The seed coat splits.

_____17. The cotyledons open up, turn green, and provide food until the true leaves develop.

_____18. The hypocotyl elongates, forms an arch, and pulls the cotyledons upward.

Steps in Seed Germination of a Dicot


Leaf
True Leaves
Cotyledon
Epicotyl
Hypocotyl
Seed Coat
Stem
Radicle
Root System

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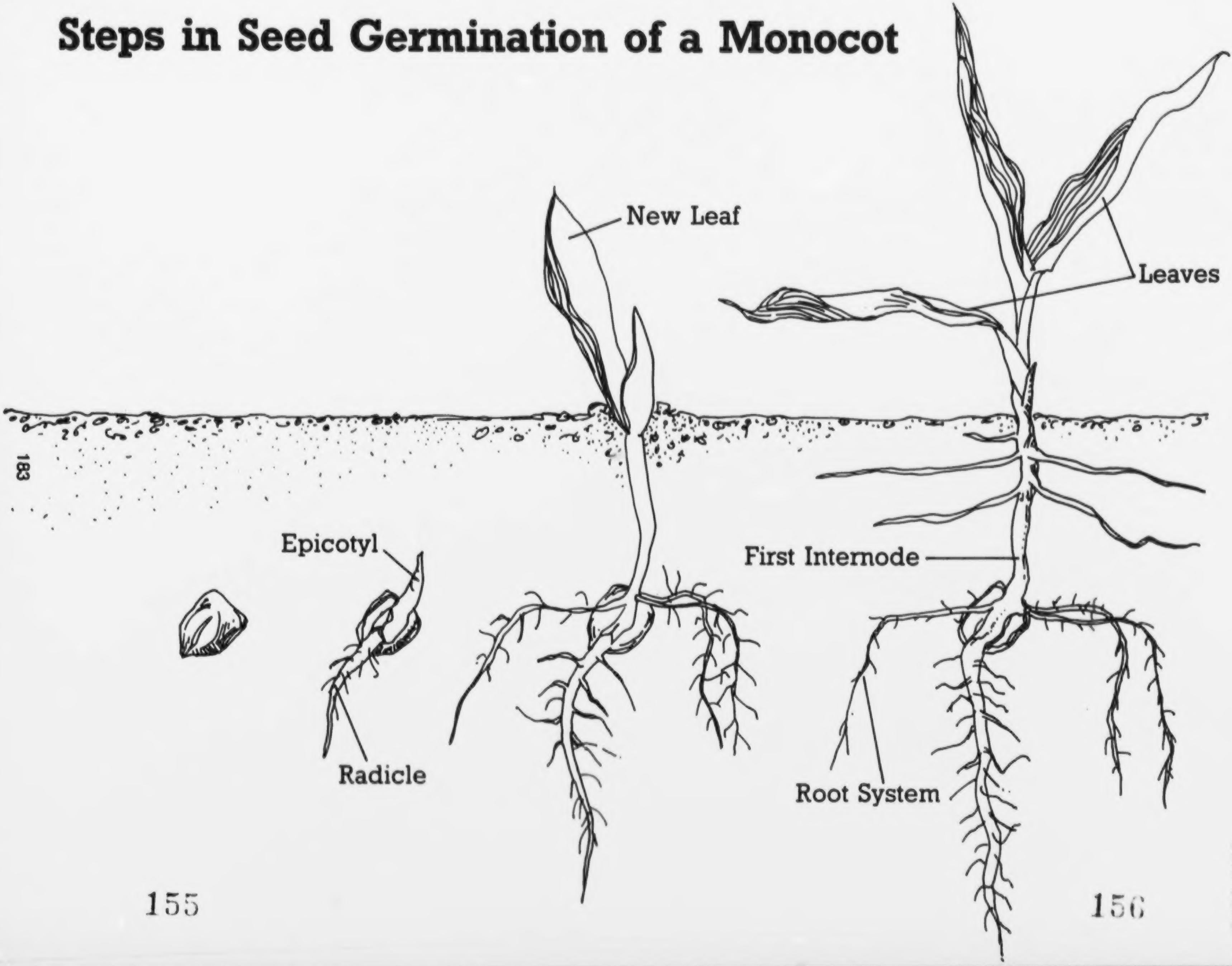
Steps in Seed Germination of a Monocot


New Leaf
Leaves
Epicotyl
First Internode
Radicle
Root System

TM 13.2

SEED PACKET INFORMATION

Obtain the following information from a seed packet label.

Name of plant: ______________________________

Variety of plant:______________________________

Company that packaged the seed: _______________

Packed for what year: _______________

Net weight: _______________

Cost: _______________

Description of plant:

Is it a(n) annual/perennial/biennial? (circle one)

Mature height: _______________

Days to germinate: _______________

Planting instructions:

    Where to plant: ______________________________

    When to plant: ______________________________

    How to plant:

        Planting depth: _______________

        Seed spacing: _______________

        Row spacing: _______________

Instructions after planting:

Job Sheet 13.1: Sowing Seed

Objective: Upon completion of this job sheet, the student will be able to sow seed.

Materials and Supplies Needed:

1. Seeds - type and number to be determined by the instructor
2. Germination medium
3. Container for germination medium
4. Clear plastic, glass, or burlap
5. Markers - permanent type marker or pencil
6. Water
7. Ruler, straight stick, or pencil
8. Plastic labels
9. Plastic or glass

Procedure:

1. Fill the container to within 3/4 inch of the top with moist germination medium.

2. Level and lightly firm the germination medium.

3. Make shallow rows 1 to 2 inches apart with the ruler. Very small seeds can be broadcast over the surface (No rows are necessary.).

4. Space seeds uniformly in rows according to spacing and depth suggested on the seed packet. Label each row or flat.

5. Cover the seeds if so directed on the seed packet with dry germination medium and moisten the surface with a fine mist of warm water.

6. Cover the flat with clear plastic or glass.

7. Place the seedling flat in a warm location (about 72°F [22°C]) for best germination.

8. Check daily for germination, lack of water, excess water, or plant diseases.

NOTE: Do not apply fertilizer when sowing the seed. When the first shoot emerges, follow recommended fertilizer strength and type for the plant species.

Job Sheet 13.2: Transplanting Seedlings

Objective: Upon completion of this job sheet, the student will be able to transplant seedlings.

Materials and Supplies Needed:

1. Individual pots or packs
2. Growing medium
3. Knife or spatula
4. Seedlings
5. Pencil or dibble
6. Water
7. Permanent marker or pencil
8. Plastic labels
9. Fertilizer

Procedure:

1. Fill individual pots or packs with moist growing medium.

2. Carefully dig up the small plants with a knife or spatula. Avoid excess loss of seedlings by digging up only small groups of seedlings and transplanting them before digging up more seedlings.

3. Gently separate seedlings and pick out individual plants to be transplanted.

   Note: If seedlings are difficult to separate, ease them apart into small groups. Then separate them into individual plants. Avoid tearing the roots. Remember, when handling seedlings hold them by their leaves, not by their stems.

4. Poke a hole in the center of the medium with a dibble or a pencil.

5. Insert seedlings slightly deeper than they were growing in the seedling flats.

6. Lightly firm the soil and water gently with warm water to settle the soil.

7. Label each transplant or group of transplants.

8. Place newly transplanted seedlings in a shaded area or cover with a shade cloth for a few days.

9. Water and fertilize plants.

   NOTE: Follow recommended fertilizer strength and type for the plant species.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 14: Asexual Plant Propagation

Objective: The student will be able to start plants by asexual propagation (vegetative techniques).

Study Questions

1. **What are the different methods of asexual plant propagation?**
2. **Why are rooting hormones used?**
3. **How are rooting hormones applied?**
4. **What tools are used for greenhouse plant propagation?**
5. **What sanitation techniques should be followed when propagating plants?**
6. **Why is it important to use labels?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Masters
   a. TM 14.1: Cuttings
   b. TM 14.2: Layering
3. Job Sheets
   a. JS 14.1: Propagation by a Stem Tip Cutting
   b. JS 14.2: Propagation by Leaf Cuttings
   c. JS 14.3: Propagation by Air Layering

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UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 14: Asexual Plant Propagation

TEACHING PROCEDURES

A. Review

Review Lesson 8: Plant Parts, Structures, and Functions.

B. Motivation

Your success as a greenhouse grower will depend in part on your knowledge and understanding of asexual plant propagation techniques. Upon completing this unit, the student will be able to propagate plants asexually using the proper techniques, with an understanding of how and why rooting hormones are applied. The student will know major tools used, sanitation techniques, and the importance of labels.

C. Assignment

D. Supervised study

E. Discussion

1. Have students list the different methods of asexual plant propagation. Discuss each method of asexual plant propagation. Use TM 14.1 and 14.2. A majority of greenhouse asexual plant propagation is done by cuttings. Simple and air layering are the major types of layering used in the greenhouse.

   What are the different methods of asexual plant propagation?

   a) Cuttings - plant pieces "cut" from the parent plant and rooted to form new plants
      1) Stem tip cutting
      2) Leaf cutting
      3) Leaf and bud cutting
      4) Stem section
   b) Division - separating clumps of plants into small groups, each having roots, stems, buds, and leaves or the potential to develop these parts
   c) Layering - method of rooting a new plant while the stem is still attached to the parent plant
      1) Simple layering - A portion of the stem is wounded, treated, and buried, leaving the terminal tip exposed.
      2) Tip layering - The terminal tip of the stem is wounded, treated, and buried.
      3) Compound or serpentine layering - The stem is alternately covered and exposed.
      4) Mound layering - The stem is cut back and buried while dormant.
      5) Trench layering - The entire plant, excluding the tip, is bent and buried.
      6) Air layering - Rooting is induced along the aboveground section of the stem.
   d) Grafting - propagating plants by inserting buds, twigs, or shoots from one plant into the stems or roots of another plant
   e) Budding - propagation by inserting a single bud into the bark of another variety
   f) Tissue culture or micropropagation - new propagation technique that uses a single cell or a few cells usually from the meristematic tissue of a plant to produce a new plant

2. Discuss with students why rooting hormones are used. If possible, show students different examples of rooting hormones.

   Why are rooting hormones used?

a) Increase the percentage of cuttings that root
b) Cause plants to root more quickly and uniformly
c) Stimulate formation of more vigorous roots

3. Demonstrate how rooting hormones are applied.

How are rooting hormones applied?

a) The recommended method of applying rooting hormones is by dusting.
    1) A squeeze bulb duster is used to apply a small amount of powder to the base of the cutting.
    2) Too much rooting powder causes the stem to rot.
b) Cuttings may be dipped in a powder or solution.
    1) If a solution of rooting hormone is used, the cuttings should be dipped in a strong solution for a short period of time.
    2) Disease organisms may spread from diseased cuttings to healthy cuttings.
    3) Throw away any left over powder or solution after dipping treatment.

4. Ask students to list the tools used for plant propagation. Display the various tools.

What tools are used for greenhouse plant propagation?

a) Sharp knife
    1) To remove and divide plant material from the parent plant
    2) To wound the plant material to induce rooting
b) Dibble stick - to make holes in the rooting medium
c) Squeeze bulb duster - to apply rooting hormone

5. Discuss with students why sanitation is important when propagating plants. Good sanitation helps prevent the spread of disease.

What sanitation techniques should be followed when propagating plants?

a) Keep knives clean and sterile when taking cuttings to help prevent the spread of diseases.
    1) Disinfect knives with rubbing alcohol or a bleach solution.
    2) Disinfect the knife after each cut.
b) Place cuttings in a sterile container to be moved to the rooting area.
    1) Use a plastic bag.
    2) Use a flat lined with newspapers.
c) Never lay cuttings on the ground or on benches.
d) Sterilize the rooting medium between each use.
e) Remove and throw away any plant debris from the benches and rooting flats.

6. Discuss the importance of using labels with students. What information should be recorded on the label? Discuss why it is important to use a permanent marker or pencil.

Why is it important to use labels?

a) Labels enable the grower to keep accurate track of all plants.
b) Labels should inform the grower of specific information.
    1) Plant name
    2) Variety
    3) Date propagated
    4) Any special treatment

NOTE: Have students complete Job Sheets 14.1, 14.2, and 14.3. The teacher may need to demonstrate the different procedures before students begin the job sheets.

F. Other activities

1. Demonstrate some of the asexual propagation methods on several different plants.
2. View "Propagating Ornamental Plants", a filmstrip from California Polytechnic State University: Vocational Education Productions, San Luis Obispo, CA.

G. Conclusion

It is essential for the greenhouse worker to be able to produce plants by asexual plant propagation, since many plants are started by asexual methods. Using rooting hormones and following good sanitation procedures ensures a good start for the plants. It is important to record the plant name, variety, date propagated, and any special treatment for the plant on the label.

H. Competency

Start plants by asexual propagation methods.

I. Answers to Evaluation

1.	b	11.	c
2.	c	12.	a
3.	a	13.	e
4.	d	14.	b
5.	d	15.	a
6.	c	16.	f
7.	a	17.	d
8.	d	18.	c
9.	d		
10.	b		

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ____________________

Lesson 14: Asexual Plant Propagation Date ____________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Stem tip cuttings should be taken with _________.

   a. Lopping shears
   b. A sharp knife
   c. Hand pruners
   d. A pruning saw

2. Cutting several veins of a broad, thick leaf is an example of which method of asexual propagation?

   a. Layering
   b. Herbaceous stem cutting
   c. Leaf cutting
   d. Leaf and bud cuttings

3. The easiest way to propagate plants that produce offset or basal shoots is _________.

   a. Division
   b. Layering
   c. Budding
   d. Grafting

4. Plants propagated using the tissue culture technique are started in _________.

   a. Flats
   b. Pots
   c. Kye-kubes
   d. Test tubes

5. Rooting hormones will increase _________.

   a. The number of plants from a cutting
   b. The rooting time
   c. The number of roots
   d. The percentage of cuttings that will root

6. The recommended method of applying rooting hormones to cuttings is to _________.

   a. Dip the cutting in a weak solution.
   b. Dip the moistened end of the cutting into the container of rooting powder.
   c. Dust the end of each cutting with the powder using a squeeze bulb duster.
   d. Apply a thin layer of powder to the surface of the rooting medium.

7. If too much rooting hormone is used, the cutting may _________.

   a. Rot
   b. Root too fast
   c. Root slower
   d. Remain unaffected

8. Successful propagation depends upon _________.

   a. The age of the plant
   b. Proper temperature
   c. The number of cuttings taken
   d. Good sanitation techniques

9. Knives used in propagation should be disinfected _________.

   a. Every week
   b. Every day
   c. After removing cuttings from each plant
   d. After each cut

10. The rooting medium should be sterilized _________.

   a. After each season
   b. After each use
   c. After every third use
   d. Once a month

11. The grower should use labels to record which of the following data?

   a. Your name, plant name, and sales date
   b. Plant name, variety, and any special treatment
   c. Plant name, variety, date propagated, and any special treatment
   d. Plant name, date of sale, special treatment, and your name

12. Which of the following is the method in which a portion of the stem is wounded and buried, leaving the tip exposed?

   a. Simple layering
   b. Compound layering
   c. Mound layering
   d. Trench layering

Match the following terms with their definition.

___13. Cuttings

___14. Division

___15. Layering

___16. Grafting

___17. Budding

___18. Tissue culture

a. Method of rooting a new plant while the stem is still attached to the parent plant.

b. Separating clumps of plants into small groups each having roots, stems, buds and leaves or the potential to develop these parts.

c. A propagation technique that can use a single cell from the meristematic tissue of a plant to produce a new plant.

d. A special form of grafting using a single bud that is inserted into the bark of another variety.

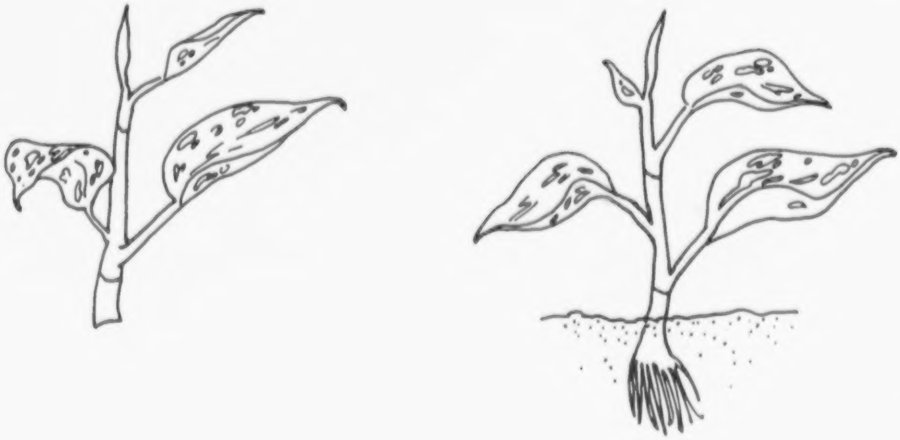
e. Plant pieces that are cut from the parent plant and rooted to form new plants.

f. Method of propagating plants by inserting buds, twigs, or shoots from one plant onto the stems or roots of another plant.

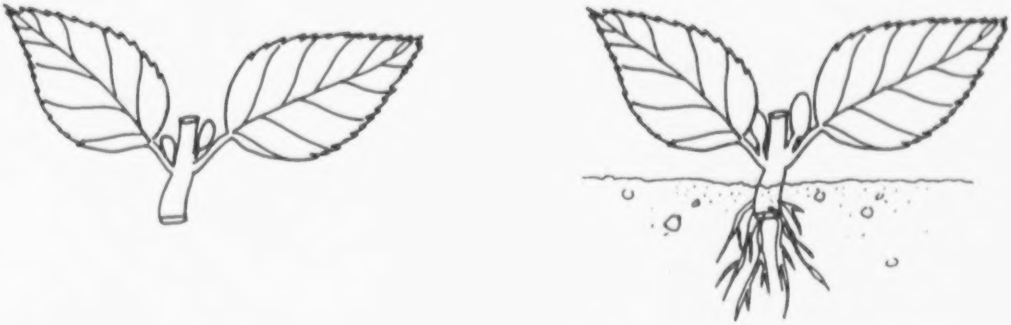
TM 14.1

Cuttings

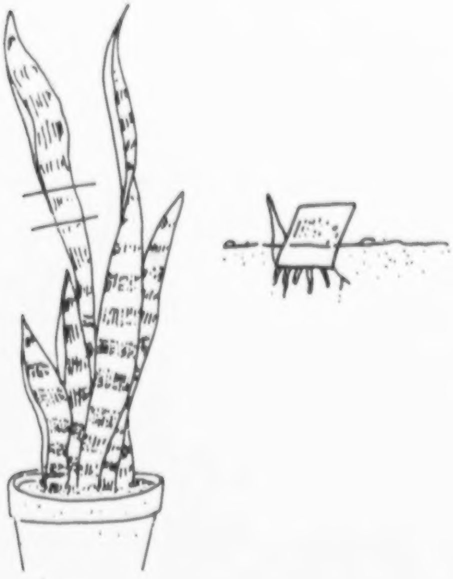
Stem Tip Cutting

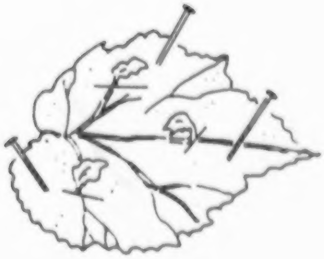


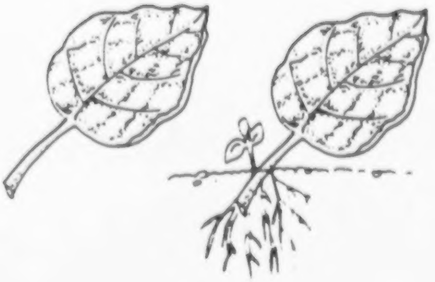
Leaf and Bud Cutting



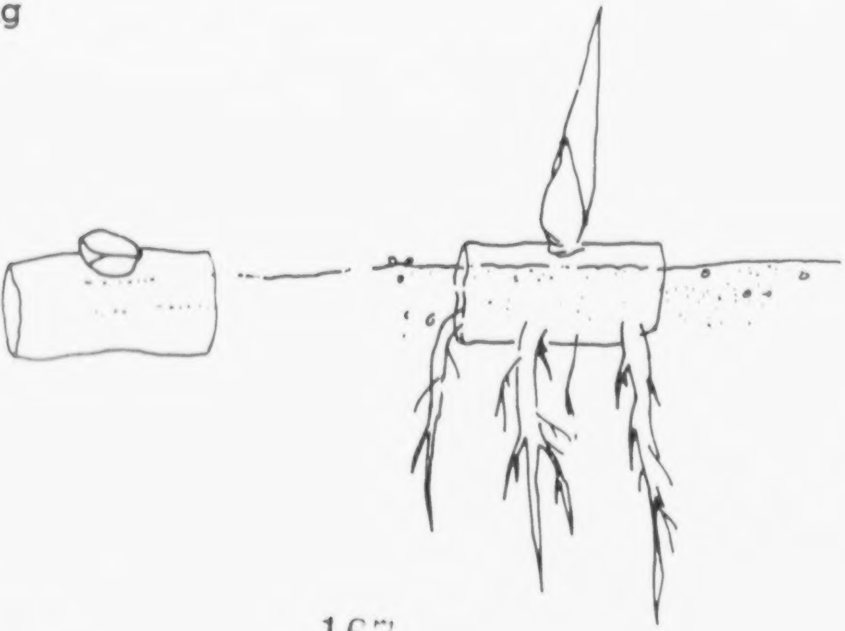
Leaf Cuttings







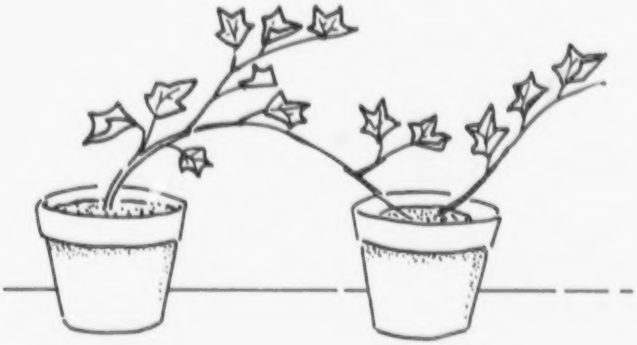
Stem Cutting



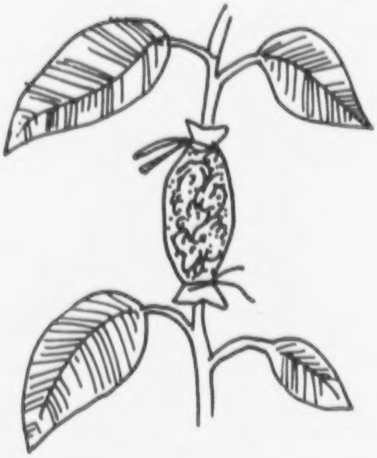
TM 14.2

Layering

Simple Layering



Air Layering



Job Sheet 14.1: Propagation by Stem Tip Cutting

Objective: After completing this job sheet the student will be able to propagate plants by a herbaceous stem tip cutting.

Materials and Supplies Needed:

1. Rooting medium
2. Clean flat
3. Plant materials such as coleus, wandering Jew, Swedish ivy, or geranium
4. Sharp knife
5. Rooting hormone
6. Squeeze bulb duster
7. Labels
8. Pencil or waterproof marking pen

Procedure:

1. Fill the flat 1/2 to 2/3 full with moist rooting medium.

2. Take at least 10 stem cuttings three inches long from the plant material being propagated. Remember to take the cutting just above a node.

3. Strip away the leaves from the bottom 1/3 to 1/2 of the stems.

4. Using the squeeze bulb duster, dust the end of each cutting with rooting hormone.

5. Insert each cutting 1 to 1 1/2 inches deep in the rooting medium. Cuttings should be spaced in rows so the foliage does not touch.

6. Place a label with the appropriate information in the flat.

7. Place the flat in the propagation bed.

8. Examine the cuttings after one week. Carefully remove each cutting by prying it gently with a label. If the roots are not 1 to 1 1/2 inches long, place the cutting back in the flat.

9. If the roots on the cutting are more than 1 to 1 1/2 inches long, transplant the cuttings to small individual pots.

NOTE: Follow proper sanitation procedures at all times.

Job Sheet 14.2: Propagation by Leaf Cuttings

Objective: After completing this job sheet, the student will be able to make leaf cuttings from several plants.

Materials and Supplies Needed:

1. Rooting medium
2. Clean flat
3. Plant materials such as a sansevieria, Rex begonia, and African violet (Check with your instructor to determine which plants to use.)
4. Sharp knife
5. Rooting hormone
6. Squeeze bulb duster
7. Label
8. Pencil or waterproof marking pen

Procedure:

1. Fill the flat 1/2 to 2/3 full with moist rooting medium.
2. Take at least 3 cuttings using each of the 3 different leaf cutting techniques.

   A.1 Take a leaf from a sansevieria. Cut the leaf into sections about 2" long. Be sure to place the leaf sections so you know which is the top and which is the bottom.

   A.2 Dust the bottom end of the leaf section with rooting hormone.

   A.3 Insert the cuttings (3) in rooting medium. Remember to put the bottom end down.

   B.1 Take a leaf from a Rex begonia. Remove the petiole.

   B.2 Cut the main veins of the leaf with a sharp knife.

   B.3 Dust the cuts with rooting hormone.

   B.4 Place the leaf flat on the rooting medium. Pin the leaf so that it lays flat with toothpicks and the cut veins are in contact with the moist rooting medium. Repeat steps B.1 through B.4 for two more leaves.

   C.1 Remove the entire leaf and petiole of an African violet from the plant with a sharp knife.

   C.2 Cut the base of the petiole at a 45° angle so that approximately 1 1/2 inches of the stem remains.

   C.3 Using a squeeze bulb duster, dust the base of the petiole with rooting hormone.

   C.4 Insert the cutting into the rooting medium. Repeat steps C.1 through C.4 for two more cuttings.
3. Cuttings should be spaced in rows so the foliage does not touch.
4. Place a label in the flat with the appropriate information.
5. Place the flat in the propagation bed.
6. Examine the cuttings for root growth by prying them up gently with a label.

7. Transplant the cuttings to individual pots when young plantlets originating from the cutting have leaves the size of a quarter or larger.

8. Clean the work area.

Job Sheet 14.3: Propagation by Air Layering

Objective: After completing this job sheet the student will be able to propagate a plant by air layering.

Materials and Supplies Needed:

1. Plant material such as rubber tree, Dieffenbachia, or Draecena
2. Toothpick or wooden matchstick
3. Sphagnum moss
4. Tie material
5. Sharp knife
6. Rooting hormone
7. Squeeze bulb duster
8. Plastic
9. Aluminum foil

Procedure:

1. Remove all leaves several inches on either side of the point on the stem where the layering wound is to be made.

2. In the center of the layering area, make a slanting cut upward almost one-third through the stem on alternate sides. Another method of wounding that can be used is to remove a strip of epidermis 1/2" - 1" wide around the stem.

3. Apply a rooting hormone to the wounded area.

4. If an upward cut is made, insert a sterile toothpick or matchstick so the cut does not heal back.

5. Take a handful of sphagnum moss that has been soaked in water. Squeeze out the excess water. Place the moist sphagnum moss around the branch where the wound has been made.

6. Cover the ball of sphagnum moss with an 8- to 10-inch-long sheet of plastic. Wrap the plastic around the moss so that it overlaps.

7. Hold the plastic in place at each end by tying it.

8. Cover the plastic with a strip of aluminum foil.

9. Check the layering several times during the period of a month to make sure the moss has not dried out.

10. After new roots are evident, remove the new plant by making a slanting cut below the moss ball. Leave the sphagnum moss around the stem to avoid injury to the new roots.

11. Pot the new plant in a container. Place the newly potted plant under a mist system until the roots have developed enough to support the plant.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 15: Growing Media

Objective: The student will be able to prepare a soilless growing medium.

Study Questions

1. **What are some functions and characteristics of an ideal growing medium?**
2. **What are some characteristics of a soil-based growing medium?**
3. **What are some characteristics of a soilless growing medium?**
4. **What are some characteristics of growing media amendments?**

References

1. Greenhouse Operation and Operation (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Masters
    - a) TM 15.1: Porosity of the Ideal Growing Medium
    - b) TM 15.2: Porosity of Field Soil
3. Job Sheet
    - a) JS 15.1: Preparing a Soilless Growing Medium

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 15: Growing Media

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

It is important to understand the functions and characteristics of various growing media, because plant growth and development are influenced greatly by medium conditions in the container.

C. Assignment

D. Supervised study

E. Discussion

1. Ask the students to discuss some functions and characteristics of an ideal growing medium. Use TM 15.1 to illustrate the porosity of the ideal growing medium.

What are some functions and characteristics of an ideal growing medium?

a) Functions
    1) Support or anchor plant in place
    2) Hold essential plant nutrients
    3) Retain sufficient water for plant growth
    4) Hold sufficient oxygen, especially for respiration of roots
b) Characteristics
    1) Loose and porous
    2) Low in nutrients initially
    3) pH level suitable for the needs of crop being grown
    4) The volume of the medium must remain constant.
    5) Dense enough to hold plant material in place, even after watering
    6) Free of unwanted seeds and weeds
    7) Free of insects, nematodes, and disease-causing organisms (i.e., pathogen-free)
    8) Must be inert or nonreactive

2. Ask the students to discuss characteristics of a soil-based growing medium. Use TM 15.2 to illustrate the importance of amending soil to be used in the greenhouse.

What are some characteristics of a soil-based growing medium?

a) Unamended soil is rarely used in greenhouses.
    1) Very heavy
    2) Poorly drained
    3) Poorly aerated
b) To make soil suitable for greenhouse use, it should be amended.
    1) Amount of amending depends on original texture.
        (a) Percent clay particles
        (b) Percent silt particles
        (c) Percent sand particles
    2) Fine soils need more amending than course soils.
    3) Loam, which is a blend of clay, silt, and sand, is the best soil for horticultural purposes.

c) Typical soil-based medium blend is sixty percent loam-type soil, twenty percent sphagnum peat moss, and twenty percent perlite.

3. Ask students to discuss some characteristics of a soilless growing medium.

What are some characteristics of a soilless growing medium?

- a) Contain no naturally-occurring soil
- b) Basically mixtures of sphagnum peat moss or processed bark and amendments such as perlite, vermiculite, sand, or calcined clay
- c) Lightweight
- d) Low in nutrients
- e) Essentially inert
- f) Well-drained, porous, and loose
- g) Fairly standard in composition
- h) Available in ready-to-use bags or may be custom-mixed in the greenhouse
- i) Two main types of soilless blends
  - a) Peat-lite mixes
  - b) Bark mixes

4. Ask the students to discuss some characteristics of growing media amendments.

What are some characteristics of growing media amendments?

- a) Organic amendments improve the growing medium by increasing water holding capacity, decreasing compaction and increasing pore space, improving structure of soil-based media, and increasing cation exchange capacity of the medium.
  - 1) Sphagnum peat moss
    - (a) Use horticultural grade of peat.
    - (b) Free of pests, weed seeds or disease-causing organisms
    - (c) Fertilizers must be applied.
    - (d) Peat is strongly acidic, therefore, limestone must be added to raise pH.
    - (e) Difficult to wet initially, but holds large amounts of water once wet
    - (f) Lightweight when dry
    - (g) Convenient to handle and store
  - 2) Processed bark
    - (a) Difficult to wet initially
    - (b) Must be supplemented with nitrogen fertilizer
    - (c) Softwood bark is preferred because it decomposes slower than hardwood bark.
    - (d) Pieces must be 1/4 inch or less in diameter
- b) Inorganic or mineral amendments improve growing media's aeration and water drainage.
  - 1) Calcined clay - special clay that has been heated to 1300 °F
    - (a) Adds bulk to medium
    - (b) High cation exchange capacity
    - (c) Improves medium structure
    - (d) Available in 50 pound bags
  - 2) Perlite - white volcanic rock that pops when heated to 1600 °F
    - (a) Improves growing media aeration
    - (b) Perlite holds up to four times its weight in water
    - (c) No cation exchange capacity
    - (d) Easy to see and mixes well into growing media
    - (e) Neutral pH
    - (f) Coarse and fine horticultural grades
    - (g) Durable, lightweight, sterile, clean, and easily handled when wet
    - (h) Also used to propagate cuttings and start seeds
  - 3) Sand
    - (a) Readily available
    - (b) Inexpensive

        (c) Particles 0.5 mm to 2 mm in diameter
        (d) Great porosity with good aeration and water drainage
        (e) Must be pasteurized before use
        (f) Adds weight to growing media to better support plants
        (g) Little water-holding capacity
        (h) Little cation exchange capacity
        (i) Essentially inert - no nutrients
    4) Vermiculite - lightweight expanded mica that has been heated to 1400°F
        (a) Contains significant magnesium, calcium, and potassium
        (b) High cation exchange capacity
        (c) High water-holding capacity
        (d) Good aeration
        (e) pH varies from neutral to very alkaline
        (f) Available in four and six cubic foot bags
        (g) Horticultural grades 2, 3, and 4; No. 3 grade most common
        (h) Use only horticultural vermiculite, not insulation vermiculite
        (i) Also used to propagate cuttings and germinate seeds
        (j) Compresses easily
        (k) Crumbles easily

NOTE: Have students complete JS 15.1. The instructor may want to demonstrate the procedure first.

F. Other activities

1. Visit a greenhouse that mixes its growing medium. Ask the manager why the various components are used. Have students write a report on their observations.

2. Visit a soil testing laboratory. Your County Extension Agent can recommend one. Write a report of observations from this field trip. Include a sample soil testing results form in your report.

G. Conclusion

Conditions in the growing medium determine a plant's root system status which in turn determine growth and development of the entire plant. Therefore, using a growing medium that meets the needs of the plants is vital when cultivating greenhouse crops. The greenhouse manager must know how the different amendments affect the growing medium, in order to make the proper blend for the plants grown.

H. Competency

Prepare a soilless growing medium.

I. Answers to Evaluation

1. c
2. b
3. b
4. c
5. a
6. d
7. Anchor or support the plant; Hold sufficient plant nutrients; Retain sufficient water; Hold sufficient oxygen
8. Any five of the following: lightweight, low in nutrients, essentially inert, well-drained, porous, loose, open, fairly standard and consistent composition, may be purchased in ready-to-use bags or custom-mixed in the greenhouse

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EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a typical formula for a soil-based growing medium?

   a. 40% loam soil, 30% sphagnum peat moss, 30% perlite
   b. 40% loam soil, 30% sphagnum peat moss, 30% vermiculite
   c. 60% loam soil, 20% sphagnum peat moss, 20% perlite
   d. 60% loam soil, 29% sphagnum peat moss, 20% vermiculite

2. Which of the following is a disadvantage of using a soilless growing medium?

   a. Natural disease and insect resistant
   b. Fertilizer must be applied on a regular basis
   c. May contain herbicides that will damage greenhouse crops
   d. Heavier in weight

3. Which of the following is a sterile, inert amendment that is added to a growing medium primarily to improve its aeration?

   a. Calcined clay
   b. Perlite
   c. Sand
   d. Vermiculite

4. What growing medium amendment may contain pathogens and therefore, should be pasteurized?

   a. Calcined clay
   b. Perlite
   c. Sand
   d. Vermiculite

5. What type of soil texture is a blend of moderate amounts of clay, silt, and sand?

   a. Loam
   b. Loam-sand
   c. Humus
   d. Muck

6. Why is unamended soil rarely used in the greenhouse today?

   a. It contains nutrients that are essential to plant growth.
   b. It is heavy to carry and ship.
   c. It will not hold sufficient water to maintain plants.
   d. It lacks the proper balance between air and water retention when placed in a pot.

Complete the following short answer questions.

7. What are the four functions of a growing medium?

   a.

   b.

   c.

   d.

8. What are five characteristics of a soilless growing medium?

   a.

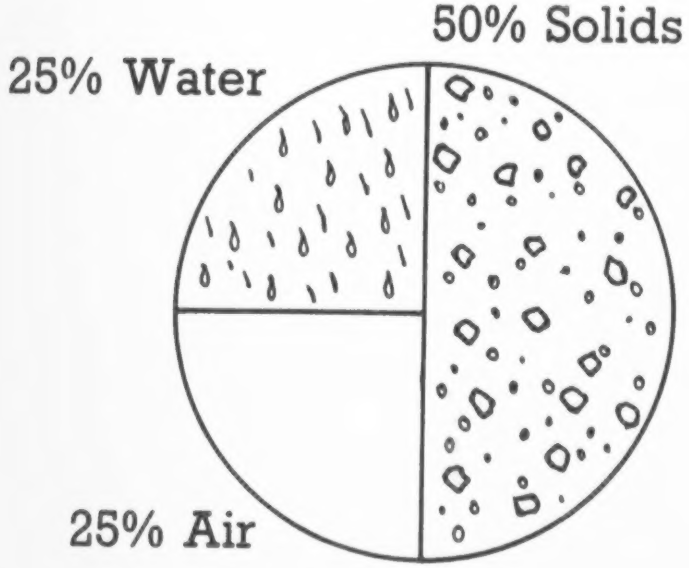
   b.

   c.

   d.

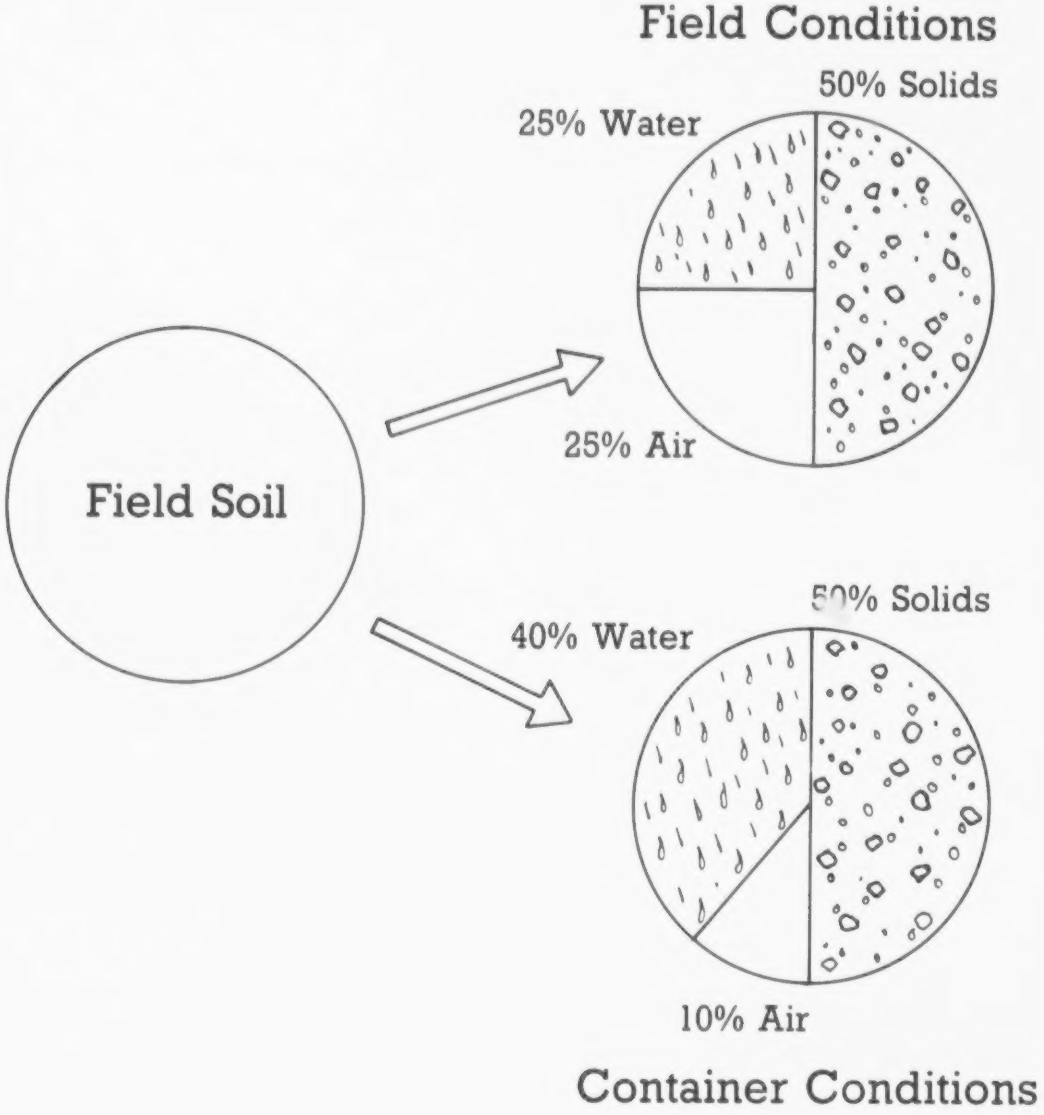
   e.

Porosity of Ideal Growing Medium



Amended Soil Media or Soilless Media

Porosity of Field Soil


Field Conditions
50% Solids
25% Water
25% Air
Field Soil
50% Solids
40% Water
10% Air
Container Conditions

Job Sheet 15.1: Preparing a Soilless Growing Medium

Objective: The student will be able to prepare a soilless medium for foliage plants.

Materials:

1. 4 oz. Ground dolomitic limestone
2. 1.2 oz. Superphosphate (0-20-0)
3. 0.5 oz. Potassium nitrate (13-0-44)
4. 0.1 oz. Fritted trace elements (FTE555)*
5. Wetting agent - read and follow label directions
6. 2 gal. Sphagnum peat moss
7. 1 gal. Medium grade vermiculite
8. 1 gal. Course grade perlite

*If this material is not available, another form of trace elements may be substituted at the rate specified by its manufacturer.

Equipment:

1. Shovel
2. Scale capable of weighing small amounts
3. Plastic sheets

Mixing Procedure:

1. Thoroughly blend together the first four ingredients until they are well-mixed.

2. Prepare a supply of water with the wetting agent. The amount of water will depend upon the amount of plant mix being prepared. Follow the wetting agent container directions.

3. Prepare the sphagnum peat moss by spreading it out on a large, clean plastic sheet. Using the water prepared in step 2, sprinkle the peat until it is thoroughly moistened. Break up any clumps of peat moss until all particles are 1/2 inch or smaller. Sprinkle with water again, if needed. Dry peat is difficult to wet and requires a great deal of water.

4. On another clean plastic sheet, alternate shovelfuls of the peat moss, vermiculite, and perlite. Continue shoveling into piles until these three ingredients are well-mixed.

5. Level the mixture evenly on the plastic and sprinkle the fertilizer ingredients blended in step 1 evenly over the top.

6. Blend all ingredients by tossing them together by shovelfuls onto a pile. Continue shoveling from pile to pile until the ingredients are thoroughly mixed.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 16: Containers

Objective: The student will be able to identify the basic types and sizes of containers used in the commercial greenhouse.

Study Questions

1. **What is the composition of growing containers?**
2. **What are some advantages and disadvantages of clay, plastic, and peat containers?**
3. **How is container selection based on the type of plant grown?**
4. **What are the basic sizes of containers used in a greenhouse?**

Reference

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 16: Containers

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

It is important to be able to identify the various kinds of containers used for growing plants, including the advantages and disadvantages of each. It is also important to identify the most common shapes and sizes of containers used by commercial growers.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with students the composition of growing containers used in the commercial greenhouse. The other container materials are seldom used but need to be mentioned because some specialty greenhouse operations may use them.

   What is the composition of growing containers?

   a) Clay
   b) Plastic
   c) Others
      1) Peat moss
      2) Thin fiberboard/composition material
      3) Wood veneer
      4) Ceramic or glazed clay
      5) Concrete
      6) Glass
      7) Fiberglass
      8) Stone

2. Discuss with students the advantages and disadvantages of the primary container materials used by commercial growers.

   What are some advantages and disadvantages of clay, plastic, and peat containers?

   a) Clay - longest-used worldwide
      1) Advantages
         (a) Main advantage - clay "breathes" (porous)
            (1) Allows for excellent aeration, gas exchange between the environment and the plant root system
            (2) Allows for better water drainage to prevent overwatering (waterlogging) of the growing medium
         (b) Heavy weight of container prevents tipping over
         (c) Long-lasting
         (d) Capable of being steam sterilized
         (e) May be reused

2) Disadvantages
   (a) Main disadvantage - Plants dry out faster, therefore frequent watering is necessary.
   (b) Unsightly buildup of fertilizer residue and algae
   (c) Heavy to lift and ship
   (d) Subject to breakage
   (e) Relatively more expensive

b) Plastic - most-used in American floriculture industry today
   1) Advantages
      (a) Less expensive
      (b) Sterile when purchased
      (c) Easily sterilized with liquid disinfectant for reuse
      (d) Lightweight - easier to ship and handle
      (e) Less likely to have buildup of fertilizer residue or algae
      (f) Available in many shapes, sizes, and colors
   2) Disadvantages
      (a) Main disadvantage - Plastic is nonporous.
         (1) Reduces aeration for the plant's root system
         (2) Causes waterlogging of the plant's root system unless watering practices or growing medium is altered
      (b) Improperly stored plastic becomes brittle and cracks easily with age.

c) Peat containers - made from peat moss pressed into thin sheets and molded into shapes
   1) Advantages
      (a) Can be transplanted with the plant, thus reducing transplant shock
      (b) Made of natural material which the plant roots can penetrate
      (c) Less root damage occurs during transplanting
   2) Disadvantages
      (a) Will only last about two months
      (b) Hard to re-wet if allowed to dry out

3. Discuss with students that container selection depends upon the type of plant grown. Point out that the intended market also influences the type of container used.

How is container selection based on the type of plant grown?

a) Plant growth habit - primary factor in selecting a container
   1) Plant height
   2) Plant width
   3) Plant shape
   4) Plant's requirement for root space

b) Four basic types of florists' container shapes
   1) Standard pot - It is as wide as it is deep and is best suited for a plant that is not top heavy.
   2) Azalea pot - Since the azalea pot is 3/4 as high as it is wide, it is best for shorter plants with spreading foliage or flowers, because the wide base provides good stability for top-heavy plants.
   3) Rose pot - Because the rose pot is 1-1/2 times as tall as it is wide, it is best for perennials with large, deep root systems.
   4) Bulb pot or bulb pan - It is best for shallow-rooted plants, because it is twice as wide as it is deep.

c) Intended market
   1) Mass merchandisers - smaller pots
   2) Retail florist - larger pots

4. Discuss with students the basic sizes of containers used in a greenhouse.

What are the basic sizes of containers used in a greenhouse?

a) Individual pots

        1) 6-inch clay or 6.5-inch plastic - large, flowering plants (e.g., poinsettias or chrysanthemums)
        2) 4-inch clay or 4.5-inch plastic - geraniums
        3) 5-, 7-, and 8-inch containers - blooming and foliage plants
        4) 6-inch rose pots on up to 3 gallons - perennial, such as roses
        5) 2-, 3-, 5-, or 7-gallon containers - large foliage plants
    b) Hanging baskets - 8- or 10-inch plastic, most popular size
    c) Bedding plant pack - most popular for bedding plants and garden vegetable plants
        1) 1 to 6 individual cells per unit and 6 to 18 units per sheet
        2) Approximate sheet size - 10 by 20 inches
        3) May be sold as one sheet (flat) or individually by the unit
    d) Plastic flats - approximate size 10 by 20 inches
        1) Hold bedding plant packs
        2) Hold individual containers
        3) Used for germinating seeds
        4) Used for starting cuttings
    e) Peat containers - bedding plants and garden vegetable plants
        1) 2- to 3-inch round or square individual pots - most common
        2) Peat pellets - self-contained growing unit
            (a) After the addition of water, expanded size is 1.5 by 1.5 inches.
            (b) For direct seeding or starting plant cuttings
        3) Peat strips
            (a) Usually 6 or 12 individual square pots joined at the top to form one unit
            (b) Placed in plastic flats
            (c) May be sold as strip or separated into individual pots

F. Other activities

1. Assist students in preparing a display board to illustrate the different container sizes and container materials. Remember to include hanging baskets. Using a heavy piece of plywood, fasten the container bottoms to the board with nails, glue, or wire. Clearly label each container. This display board serves as an excellent student reference.

2. Visit a large, local retail florist. Require that the students take notes on the types of floral products on display, container sizes for each crop, and composition of the containers. Ask students to prepare a written report of their observations.

G. Conclusion

The choice of container (i.e., composition, shape, and size) is primarily determined by the growth habit of the floriculture crop being grown. The intended market also influences which container will be used.

H. Competency

Identify the basic types and sizes of containers used in the commercial greenhouse.

I. Answers to Evaluation

1. d
2. b
3. a
4. c
5. c
6. b
7. d
8. a

9. Any three of the following: lightweight, easily cleaned, easily sterilized with a liquid disinfectant, no accumulation of fertilizer residue or algae, and available in many shapes, sizes, and colors

10. Any three of the following: hold bedding plant packs, hold individual containers, germinate seeds, start cuttings, and carry plant materials from place to place

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Lesson 16: Containers

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EVALUATION

Circle the letter that corresponds to the best answer.

1. Which container material is recommended to prevent waterlogging?

   a. Wood veneer
   b. Peat
   c. Plastic
   d. Clay

2. A bulb pot is best for swallow rooted plants because it is

   a. Twice as tall as it is wide
   b. Twice as wide as it is tall
   c. One and one-half times as wide as it is tall
   d. One and one-half times as tall as it is wide

3. Which container material has excellent aeration?

   a. Clay
   b. Plastic
   c. Glass
   d. Fiberglass

4. Bedding plant packs would typically be used to grow which crops?

   a. Bulb crops, such as tulips
   b. Perennial, such as roses
   c. Bedding plants, such as tomatoes
   d. Large flowering plants, such as poinsettias

5. Which of the following is the most common container material used for commercial greenhouse production?

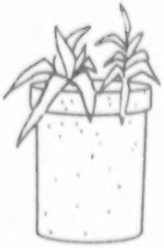
   a. Peat
   b. Clay
   c. Plastic
   d. Fiberboard/composition material

6. What is the recommended container shape to prevent a short top-heavy plant from tipping over?

   a. Rose pot
   b. Azalea pot
   c. Standard pot
   d. Peat pot

7. Which of the containers pictured below is in the right proportion with its plant?

a.



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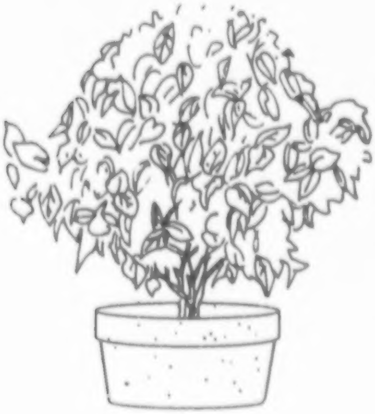

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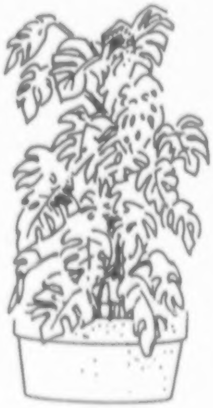

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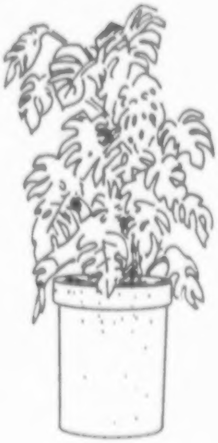


8. Which of the following is not an advantage of using clay as a container material?

a. Subject to breakage
b. Long-lasting
c. Porous
d. Can be cleaned

Complete the following short answer questions.

9. What are three advantages of using plastic containers?

a.

b.

c.

10. What are three common uses of plastic flats?

a.

b.

c.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 17: Proper Watering

Objective: The student will be able to describe the various factors involved in the proper watering of greenhouse plants.

Study Questions

1. **What are the effects of improper watering on plant growth?**
2. **What are the three rules of proper watering?**
3. **What factors determine the moisture holding capacity of a plant growing medium?**
4. **What is meant by overhead, surface, and subsurface watering?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Transparency Masters
    - a) TM 17.1: Water Retention vs. Container Height
    - b) TM 17.2: Location of Water and Air in Container
    - c) TM 17.3: Water Retention, Container Height, and Medium Porosity

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 17: Proper Watering

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

Although watering appears to be a simple operation, improper watering is more frequently responsible for loss of crop quality than any other cultural operation. Therefore, to produce top quality crops students must learn the essentials of proper watering.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with the students the primary considerations surrounding the proper watering of greenhouse crops.

   What are the effects of improper watering on plant growth?

   a) Underwatering
      1) Plant wilts
      2) Photosynthesis restricted
         (a) Slower plant growth
         (b) Smaller leaves
         (c) Shorter internodes
         (d) Hardened plant tissues
      3) Tip burn in extreme cases
   b) Overwatering
      1) Restricts oxygen to root system
      2) Damages roots
      3) Restricts water uptake
         (a) Wilting
         (b) Stunting
         (c) Nutrient deficiencies
         (d) Death of plant
      4) Encourages disease invasion of root system

2. Discuss with students the three rules of proper watering.

   What are three rules of proper watering?

   a) Use a well-drained growing medium.
      1) Coarse texture
      2) Highly porous yet water retentive
      3) Contains adequate amounts of air after being watered
   b) Water thoroughly at every watering.
      1) Ten percent more (by volume) than pore space of growing medium in pot (e.g., 10-12 ounces of water per 6-inch azalea pot)
      2) Assures maximum water retention by growing medium
      3) Leaches excess salts
   c) Water plants as needed.

1) Plant starts to wilt.
2) Growing medium feels dry or it turns lighter in color.

NOTE: The growing medium should not be touched if pesticides have been applied or if your hands are not clean.

3. Discuss with the students the factors that determine the growing medium's moisture holding capacity. Use TMs 17.1, 17.2, and 17.3.

What factors determine the moisture holding capacity of a plant growing medium?

a) Porosity of the medium
    1) Larger pores (noncapillary) are filled with air following watering and drainage.
    2) Smaller pores (capillary) are filled with water following watering and drainage.
    3) Ratio of large to small pores is one factor that dictates amount of air and water growing media will contain following watering and drainage.
b) Depth of growing medium (height of container)
    1) Water retention is a result of the interaction between the capillary forces of the growing medium and the pull of gravity.
    2) Taller container - Gravity exerts greater influence because of increased height of water column in medium.
    3) Shallow container - Growing medium is able to retain more water against gravity's pull.
    4) In any container and with any medium, there is less water at top than bottom because of gravitational pull.
    5) Use a more porous medium for shallow containers.
    6) Less porous medium is more appropriate for taller containers.

4. Discuss the advantages and disadvantages of the different water application methods. Review the different watering systems discussed in Lesson 5.

What is meant by overhead, surface, and subsurface watering?

a) Overhead
    1) Foliage wetted as plant is watered
        (a) May encourage disease infestation
        (b) May leave salt residue on leaves
        (c) May wash or puddle growing medium
    2) Manual or automatic systems available
b) Surface
    1) Water applied at surface of growing medium without wetting foliage
        (a) Helps prevent diseases
        (b) No salt residue on leaves
        (c) Medium less likely to puddle or be washed from pot
    2) Usually applied with manual or automatic devices
c) Subsurface
    1) Water is absorbed through the bottom of the container.
    2) Contact between water and growing medium in pot must be established.
    3) Growing medium is wetted through capillary action. Water climbs up medium inside pot.
    4) There must be a proper balance between porosity of medium and pot height.
        (a) Too porous - Water will not climb to top portion of pot.
        (b) Not porous enough - Medium will become waterlogged.
    5) There may be a salt buildup in growing medium unless pots are leached periodically.

F. Other activities

1. Obtain three equal-sized plants of an herbaceous species such as coleus that wilts easily when water stressed. Water one plant by placing it in a basin of water so that the root zone is covered with water. Water the second plant only when severe wilting occurs. Water the third plant so that the growing medium is kept uniformly moist (neither wet nor dry). After six weeks observe differences in rate of growth, leaf surface area, and internode length.

2. Demonstrate the effect of container height on water content of medium by using an ordinary small household sponge (approximately 1/2 x 3 x 5 inch size). Holding the sponge flat in the palm of your hand, saturate it with water and allow it to drip until excess moisture is drained. Point out to students that the sponge is nearly saturated from top to bottom and that the pores within the sponge are filled with water. Equate this to the medium in a shallow pot. Next, slowly turn the sponge on its side (3 inches high) being careful not to squeeze it. You will note that additional water will drain from the sponge because the height of the water column in the sponge has been increased from one-half inch to three inches. This causes more water to be "pulled" by gravity from the sponge filling more pore spaces with air. Have students note that the bottom part of the sponge is still saturated while the top part is drier. Compare this to a medium-sized pot. Finally, carefully tip the sponge on its end (5 inches high). Note again that more water will drain because the water column has again been increased in height, causing more water to be "pulled" by gravity out of the sponge. Show students that there still is a small portion at the bottom of the sponge completely saturated with water. However, the further toward the top of the sponge, the drier it has become (more pore spaces filled with air rather than with water). Compare this to a tall pot.

3. Take a tour of a greenhouse and note the types of watering systems used. Note the amount of automation in each case.

G. Conclusion

Water is a key environmental component affecting crop quality in greenhouse production. By knowing the effects of improper watering on plant growth, the factors affecting the water-holding capacity of growing media, the proper way to water plants, and the various water application methods, the greenhouse manager will be able to manipulate water to optimize plant growth.

H. Competency

Describe the factors involved in the proper watering of greenhouse plants.

I. Answers to Evaluation

1. c
2. d
3. a
4. a
5. c
6. a
7. Porosity of medium
   Depth of medium (height of container)

UNIT II - GREENHOUSE OPERATION AND MANAGEMENT

Name ____________________

Lesson 17: Proper Watering

Date ____________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is the initial symptom of a plant growing in a moisture deficient environment?

    a. Smaller leaves
    b. Tip burn of leaves
    c. Wilted leaves
    d. Root rot

2. What is the primary cause leading to the symptoms of overwatering?

    a. Causes the roots to take up too much water
    b. Cools the growing medium thus limiting the rate of root growth
    c. Releases excess chlorine to the growing medium thus injuring delicate roots
    d. Excludes oxygen from the plant's root system

3. Which of the following is not one of three rules of proper watering?

    a. Never water during the hottest part of the day.
    b. Water plants when moisture stress begins.
    c. Water thoroughly at every watering.
    d. Use a well-drained growing medium.

4. How much more water (by volume) should be applied at each watering than can be held by the growing medium?

    a. 10%
    b. 15%
    c. 20%
    d. 50%

5. Large (noncapillary) pores hold ______ in the growing medium whereas small (capillary pores) hold ______.

    a. Water, water
    b. Water, air
    c. Air, water
    d. Air, air

6. Which water application method is most likely to encourage foliage diseases?

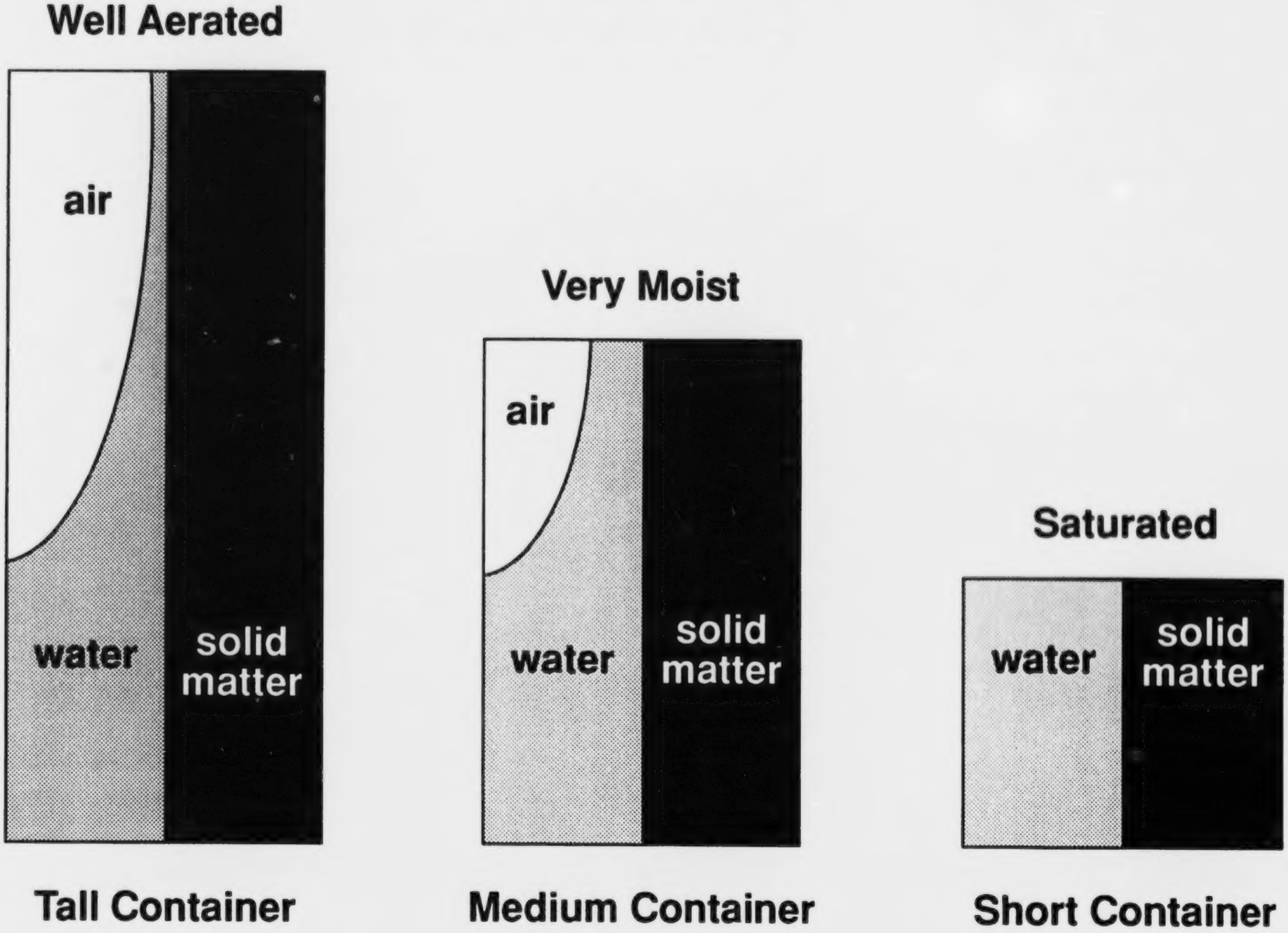
    a. Overhead
    b. Surface
    c. Subsurface
    d. None of the above

Answer the following short answer question.

7. What two major factors influence the amount of water held in a container?

TM 17.1

Water Retention vs. Container Height



Well Aerated

air

water

solid matter

Tall Container

Very Moist

air

water

solid matter

Medium Container

Saturated

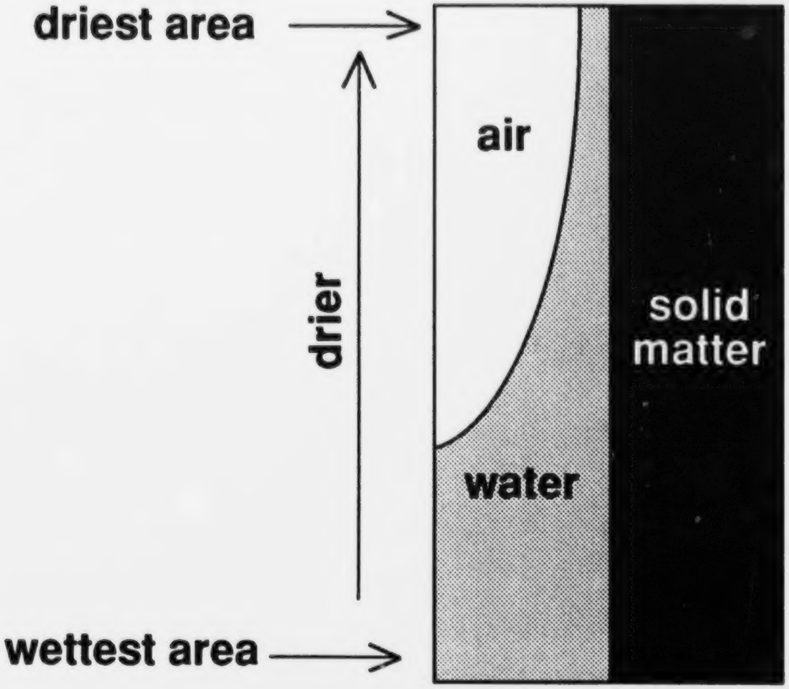
water

solid matter

Short Container

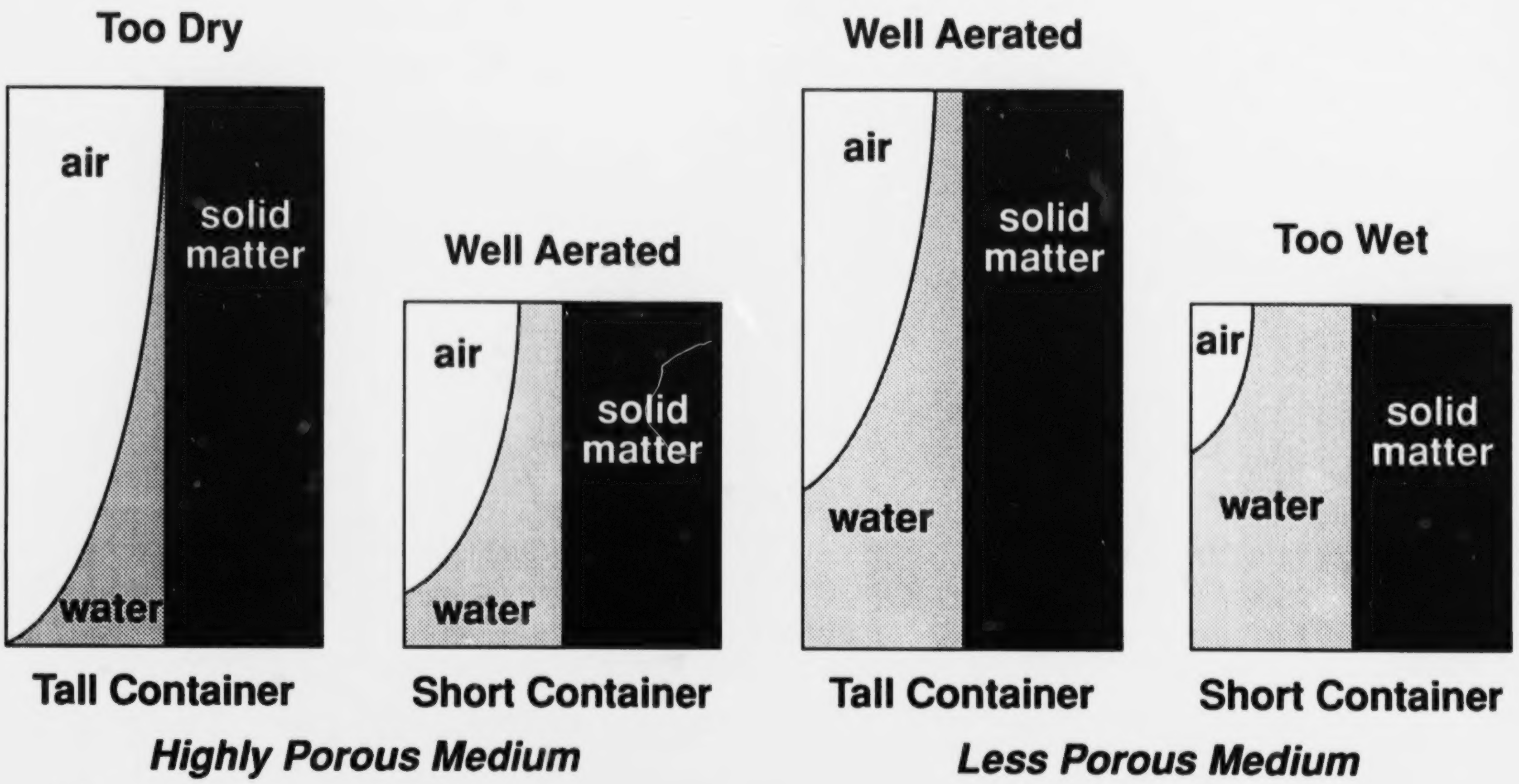
TM 17.2

Location of Water and Air in Container


driest area
drier
air
water
solid matter
wettest area

Container

Water Retention, Container Height, and Medium Porosity


Too Dry
air
solid matter
water
Tall Container
Well Aerated
air
solid matter
water
Short Container
Highly Porous Medium
Well Aerated
air
solid matter
water
Tall Container
Too Wet
air
solid matter
water
Short Container
Less Porous Medium

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 18: Fertilizers and Plant Nutrition

Objective: The student will be able to describe the principles and techniques for proper fertilization of greenhouse crops.

Study Questions

1. **Why fertilize a greenhouse-grown plant?**
2. **What elements are essential for plant growth?**
3. **What are the major nutrient deficiency symptoms?**
4. **How and why is the growing medium tested?**
5. **What are the two fertilizer categories?**
6. **What are the different forms of fertilizers?**
7. **How are fertilizers applied?**
8. **What does the fertilizer formula mean?**
9. **How is the fertilizer concentrate for the stock tank calculated?**
10. **How is a hose siphon fertilizer injector calibrated?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Assignment Sheet
    a) AS 18.1: Calculating Fertilizer
3. Job Sheet
    a) JS 18.2: Effect of Nitrogen on the Growth of Tomato Seedlings

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 18: Fertilizers and Plant Nutrition

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

Proper plant nutrition is one of the keys to successful plant production. Fertilizers provide essential elements for good plant nutrition. It is important to be able to identify the various types of fertilizers used to provide plant nutrition, as well as their methods and rates of application.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with students the reasons for fertilizing plants.

Why fertilize a greenhouse-grown plant?

a) Greenhouse-grown crops have the highest nutritional requirements in all of agriculture. (e.g., One acre of chrysanthemum plants require 4,000 pounds of nitrogen per year.)
b) The proper amount of fertilizer must always be available for optimum plant growth.
    1) Quick growth rate means rapid sale of crop plants.
    2) Quicker crop turnover means more profit for the greenhouse owner.

2. Discuss with students the elements necessary for plant growth.

What elements are essential for plant growth?

a) The first category of required elements are those available in unlimited amounts in air and water: carbon, oxygen, and hydrogen.
b) The second category includes the mineral elements absorbed by the plant's roots.
    1) The macronutrients needed in large amounts by plants are nitrogen, phosphorus, and potassium.
    2) The secondary macronutrients -- calcium, magnesium, and sulfur -- are needed in moderate amounts by plants.
    3) The micronutrients or trace elements -- iron, zinc, manganese, molybdenum, boron, chlorine, and copper -- are required in small amounts by plants.

3. Discuss with students the major nutrient deficiency symptoms. A key to nutrient deficiencies is included in the student reference.

What are the major nutrient deficiency symptoms?

a) A large variety of plant nutrient deficiency symptoms (e.g., slow growth, stunting, foliage discoloration, especially yellowing, and premature leaf drop) are possible.
b) Nutrient deficiency symptoms vary widely according to the type of plant and variety.
c) Some nutrient deficiency symptoms may be due to an environmental cause (e.g., lack of water or low temperatures); such causes are also called physiological causes.
d) A key to nutrient deficiency symptoms is helpful in identifying which essential nutrient is deficient.

4. Discuss with students why the growing medium should be tested. The instructor may want to obtain a sample print-out from the local University Extension Office.

How and why is growing medium tested?

- a) General properties of the growing medium may be checked.
  - 1) Soil-based media are usually tested by personnel at a University Extension Office. Field soil as well as soil-based media may be tested.
  - 2) Private firms will analyze soilless growing media.
  - 3) The results provide a wealth of information to evaluate the current fertilization program and to make adjustments, if needed.
- b) It is important to check growing medium pH.
  - 1) Growing media may range from a pH of 1.0 (most acidic) to a pH of 14.0 (most alkaline or basic). Neutral pH is 7.0.
  - 2) Most floriculture crops grow best at a pH of 5.5 to 6.5.
  - 3) Most of the essential nutrient elements are available for uptake by plant roots only within specific pH limits.
  - 4) A pH meter can be used to test the pH level. Procedures for use vary according to the type of meter used.
- c) The amount of soluble mineral salts accumulating in the growing medium may be determined.
  - 1) Soluble salts originate from irrigation water, fertilizer residues, and from the growing medium.
  - 2) Insufficient soluble salt levels will cause nutrient deficiency symptoms, such as slowed plant growth.
  - 3) Excess soluble salt levels may injure plant root systems.
  - 4) A salinity meter is a device that may be used to determine soluble salt levels in the growing medium.

5. Discuss with students the definition of a fertilizer.

What are the two fertilizer categories?

- a) The first fertilizer category contains those made from once-living or organic sources.
  - 1) Organic fertilizers release their nutrients slowly to plant roots.
  - 2) Organic fertilizers contain relatively low amounts of nutrients.
  - 3) Organic fertilizers may occur naturally (e.g., animal manure or green sand) or be processed (e.g., fish emulsion or bone meal).
- b) The second category of fertilizers contain those made from nonliving or inorganic sources.
  - 1) Inorganic fertilizers release their nutrients quickly.
  - 2) Inorganic fertilizers are readily available for plant growth.
  - 3) Inorganic fertilizers are highly concentrated; too much can injure plant roots.

6. Discuss the different forms of fertilizers with students. Discuss the most commonly used form of fertilizer in commercial greenhouses.

What are the different forms of fertilizers?

- a) The most common is dry granules that are dissolved in water.
- b) Some dry fertilizers are mixed into the growing medium prior to planting.
- c) Other dry fertilizers are applied as a top dressing to the soil surface.
- d) Dry fertilizers may be formed into tablets or sticks, which are placed in the soil
- e) Slow-release or controlled-release fertilizers release their nutrients over a long time period as they are broken down by water and soil bacteria.
- f) Several slow-release fertilizers supply only trace elements.

7. Discuss with students ways that fertilizers are applied.

How are fertilizers applied?

a) The most important factor for successful fertilization is to carefully follow label directions.
b) Before applying any fertilizer, make sure that the medium is moist.
c) When incorporating a dry fertilizer into the growing medium, always water the medium before transplanting a plant into it.
d) Water soluble inorganic dry granular or liquid fertilizers are widely used.
    1) They are refined, pure, easily dissolved in water, and quickly absorbed by plant roots.
    2) They must be reapplied on a regular basis because they are readily leached from the growing medium.
    3) They can injure roots if applied to dry soil or applied at too high of concentrations.
    4) They are commonly used in automatic fertilizer injectors or proportioners; when applied through the irrigation system.
    5) They are frequently used at low concentrations in constant liquid feeding (CLF) programs.

8. Discuss the meaning of the fertilizer formula with students.

What does the fertilizer formula mean?

a) Any fertilizer containing the elements nitrogen, phosphorus, and potassium is know as a "complete" fertilizer.
b) The label on the fertilizer bag states the fertilizer analysis or formula.
c) A label indicating 20-20-20 means that this fertilizer contains 20 percent nitrogen, 20 percent phosphorus expressed as P_2O_5, and 20 percent potassium expressed as of K_2O by weight.

9. Discuss with students the way the fertilizer concentrate for the stock tank is calculated. Have students complete AS 18.1. The instructor may need to work through the calculations with students.

How is the fertilizer concentrate for the stock tank calculated?

a) The fertilizer concentrate in a stock tank solution may be based on any essential nutrient element, although it is usually based upon the amount of N.
b) Always check the fertilizer injector or fertilizer proportioner for the correct dilution ratio setting; dilution ratios are usually between 1:12 and 1:500.
c) Use the following formula to calculate the amount of dry fertilizer to make the stock tank concentrate:

$$\frac{\text{injector ratio:1}}{\text{\% nutrient in dry fertilizer}} \times \frac{\text{desired ppm nutrient}}{100} \times 1.35 \times \text{Gal. in stock tank} = \text{No. oz. of fertilizer for stock solution}$$

11. Discuss with students the way a hose siphon fertilizer injector is calibrated. Demonstrate how it is calibrated.

How is a hose siphon fertilizer injector calibrated?

a) The hose-siphoning type fertilizer proportioner may be used for applying fertilizers.
b) The hose siphon proportioner device is connected between the water outlet and the hose, with a tube extending down into a pail of concentrated fertilizer solution; the suction of water flowing through the hose pulls up the fertilizer solution from the pail into the hose to mix with the water.

c) The hose siphon proportioner is durable, inexpensive, and easy to use. It is a fairly accurate way of measuring fertilizer for application.
d) A hose siphon proportioner has one main disadvantage: because of reduced flow rate, watering time is lengthened.
e) The dilution ratio must be calculated for a hose siphon; calibrated dilution ratios usually range between 1:12 and 1:16.
f) The calibrated dilution ratio is used for calculating the amount of dry fertilizer to be added when making the stock tank concentrate.

F. Other activity

Invite a local greenhouse owner or manager to discuss the importance of proper fertilizer application.

G. Conclusion

Proper nutrient levels are necessary for optimum plant growth. Applying proper nutrients to greenhouse-grown plants results in a faster growth rate, thereby resulting in quicker sale and greater economic return for the crop.

H. Competency

Describe the principles and techniques for proper fertilization of greenhouse crops.

I. Answers to Evaluation

1. a
2. c
3. d
4. b
5. a
6. c
7. Organic fertilizers are from once-living sources, inorganic fertilizers are manmade from nonliving sources such as minerals
8. Fertilizers
9. Because it may cause root injury to the plant

J. Answers to AS 18.1

1. 5 lbs N, 2.5 lbs P_2O_5, 5 lbs K_2O
2. 46% x 500 = 230 lbs
3. 2,000 lbs x 2.0% = 40 lbs
4. $\frac{128}{20\%} \times \frac{200\text{ ppm}}{100} \times 1.35 \times 5\text{ gal.} = 86.4\text{ oz}$
5. $\frac{200}{20\%} \times \frac{300\text{ ppm}}{100} \times 1.35 \times 1\text{ gal.} = 40.5\text{ oz}$

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Name ____________________

Lesson 18: Fertilizers and Plant Nutrition

Date ____________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Chrysanthemum plants prefer a growing medium pH of 5.5-6.5. What would this pH range be considered?

   a. Acidic
   b. Alkaline or basic
   c. Neutral
   d. None of the above

2. A complete fertilizer must contain what three nutrient elements?

   a. Calcium, magnesium, and sulfur
   b. Iron, zinc, and molybdenum
   c. Nitrogen, phosphorus, and potassium
   d. Boron, chlorine, and copper

3. How many elements are essential for plant growth and development?

   a. 3
   b. 6
   c. 9
   d. 16

4. Most greenhouse crops flourish when grown in what growing medium pH range?

   a. 5.0 - 5.5
   b. 5.5 - 6.5
   c. 6.5 - 7.5
   d. 7.5 - 8.0

5. A 100 pound bag of 15-16-17 fertilizer contains how many pounds of N?

   a. 15
   b. 16
   c. 17
   d. 20

6. The fertilizer concentration of a stock tank solution is usually based on the amount of ________ in ppm to be fed to the plants, although it may be based on the amount of any essential nutrient.

   a. Potassium
   b. Phosphorous
   c. Nitrogen
   d. Magnesium

Complete the following short answer questions.

7. Name and briefly define the two main categories of fertilizers.

   a.

   b.

8. What substance can be applied to plants with a hose siphon proportioner?

9. Why is it not recommended to apply fertilizer to dry growing medium?

CALCULATING FERTILIZER

Answer the following questions about calculating fertilizer.

1. A 25 pound bag of general purpose 20-10-20 fertilizer would provide ____ pounds of N, ___ pounds of P_2O_5, and ____ pounds of K_2O.

2. Urea is an organic fertilizer containing 46% N. How much N is there in 500 pounds of urea?

3. How much potassium in the form of K_2O is found in one ton of poultry manure having an analysis or formula of 1.5-1.7-2.0?

4. Calculate the number of ounces of 20-10-20 fertilizer that must be dissolved in 5 gallons of stock solution to feed 200 ppm N to the plants using a 1:128 fertilizer injector.

5. A floriculturist desires to feed via an automatic fertilizer injector 300 ppm N of a 20-10-20 dry fertilizer using a 1:200 injector ratio. Calculate the number of ounces of dry fertilizer that must be added to one gallon of the stock solution.

Job Sheet 18.1: Effect of Nitrogen on the Growth of Tomato Seedlings

Objective: After completing this job sheet the student will be able to determine the optimum N fertilizer rate for tomato seedlings, as well as determine N deficiency and toxicity symptoms.

Materials and Supplies Needed:

1. 40 tomato seeds of the same variety
2. 40 3-inch peat pots
3. Germination medium
4. Labels
5. Pencil or waterproof marking pen
6. Fertilizer solution of 50 ppm N
7. Fertilizer solution of 200 ppm N
8. Fertilizer solution of 400 ppm N
9. Ruler or yardstick
10. Sharp knife
11. Analytical balance capable of weighing small amounts (grams)
12. Colored pens or markers

Procedure:

1. Fill the peat pots with moist germination medium.

2. Make a hole, with finger, approximately 1/2 inch deep in the center of each pot.

3. Drop one tomato seed into each hole.

4. Gently firm the medium over the seed.

5. Water the newly-seeded pots with plain water until it runs form the bottom and sides.

6. Set the pots in a warm, sunny place.

7. Check them everyday and keep them well-supplied with plain water. Do not let them dry out for this might damage the seed.

8. After germination occurs and the seedlings have produced their first set of true leaves, begin the following fertilizer routine for four to six weeks.

   a. To the first block of 10 pots, the control group, apply only plain water. Place a label with this information in each pot.

   b. To the second block of 10 pots, water with a fertilizer solution of 50 ppm N at every watering. Place a label with this information in each pot.

   c. To the third block of 10 pots, water with a fertilizer solution of 200 ppm N at every watering. Place a label with this information in each pot.

   d. To the fourth block of 10 pots, water with a fertilizer solution of 400 ppm N at every watering. Place a label with this information in each pot.

9. After the four- to six-week period is up, measure and record the height of each seedling.

10. To determine the average height for each block of seedlings, add all the height measurements in the block and divide this answer by the number of plants in the block. Do this for each block of plants.

11. With a sharp knife, cut each seedling off at the growing medium line and weigh the aboveground portion of each. Record individual weights.

12. To determine the average weight for each block of seedlings, add all weight measurements for the block and divide this answer by the number of plants in the block. Do this for each block of plants.

13. Draw a graph to show the average height of the tomato seedlings in each block. Use different colored pens or markers for each block.

14. Draw a graph to show the average weight of the tomato seedlings in each block. Use different colored pens or markers for each block.

15. Write a conclusion to answer the following questions:

    a. What is the purpose of growing a control group?

    b. Judging from the two graphs, what is the optimum N fertilizer rate for these tomato seedlings?

    c. After examining the plants, is there a block showing N deficiency symptoms and, if so, what are the symptoms observed?

    d. Is there a block possible showing N toxicity symptoms and, if so, what are the symptoms observed?

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 19: Common Greenhouse Pests and Diseases

Objective: The student will be able to identify common pests and diseases found in greenhouses.

Study Questions

1. **What are nine categories of plant pests?**
2. **What are the major mouth types and body parts of an insect?**
3. **What are the eight major greenhouse pests?**
4. **What are the three categories of plant diseases?**
5. **What are the four major diseases of greenhouse crops?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Assignment Sheet
    a) AS 19.1: Common Greenhouse Pests

Lesson 19: Common Greenhouse Pests and Diseases

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

Proper identification of the common pests and diseases found in greenhouses is important in order to effectively control them.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss plant pests with students. Point out that insects and mites represent the biggest problem for greenhouse plant production.

   What are nine categories of plant pests?

   a) Arachnids - animals with eight legs such as mites
   b) Bacteria - parasitic one-celled organisms, usually without chlorophyll
   c) Fungi - one-celled to multi-celled parasitic organisms without chlorophyll
   d) Insects - animals with six legs and three body parts as adults
   e) Mollusks - invertebrate animals with soft bodies such as slugs and snails
   f) Nematodes - invertebrate roundworms such as soil nematodes
   g) Rodents - vertebrate animals such as mice and rats
   h) Viruses - parasitic particle consisting of a DNA or RNA core surrounded by a protein sheath and much smaller than a cell
   i) Weeds - any plant growing out of place

2. Discuss the major mouth parts and body parts of an insect with students. Point out the importance of being able to identify insects.

   What are the major mouth types and body parts of an insect?

   a) Mouth types
      1) Chewing - larvae of fungus gnats and shore flies
      2) Rasping-lapping - thrips and bees
      3) Piercing-sucking - aphids and scale insects
   b) Body parts
      1) Head
      2) Thorax
      3) Abdomen

3. Discuss the eight major greenhouse pests. Point out that there may be other pests as well but these eight cause the most damage. If possible, show plants that have been damaged by the pests. The approximate size for each pest is given. Have students complete AS 19.1 for each of the following eight pests. The instructor will need to make duplicate copies of the assignment sheet.

What are the eight major greenhouse pests?

a) Aphids (plant lice) - insects
  1) Most common greenhouse pest - green peach aphid
  2) Adult size - 1/25-1/8 inch (1-3 mm)
  3) Piercing-sucking mouth parts
  4) Plant symptoms - stunting and distortion of new shoots, spread bacteria and viral diseases between plants, give off honeydew which is food source for sooty black mold fungus and attracts ants, tiny yellow spots on foliage
b) Whiteflies - insects
  1) Adult size - 1/16 inch (2 mm)
  2) Piercing-sucking mouth parts
  3) Plant symptoms - tiny yellow spots on foliage, give off honeydew, spread plant diseases between plants
  4) Trap plants (e.g., fuchsias) attract whiteflies.
  5) Yellow boards or strips coated with a sticky substance physically catch whiteflies.
c) Mites - arachnids
  1) Most difficult pest to control and causes most economic damage
  2) Very small, less than 1/50 inch (0.50 mm) long
  3) Piercing-sucking mouth parts
  4) Plant symptoms - tiny yellow spots on foliage, curled leaves, bronze foliage, spider mites weave tiny webs which turn leaves brown
d) Thrips - insects
  1) Adult size - 1/25 inch (1 mm)
  2) Rasping-lapping mouth parts
  3) Plant symptoms - malformed new growth and flowers, streaking and browning of flower petals, leaf and flower drop
  4) Spread plant diseases between plants
  5) Use very fine screening on all greenhouse openings.
  6) Locate vents perpendicular to prevailing winds.
e) Mealybugs - insects
  1) Adult size - 1/8-3/8 inch (3-4 mm)
  2) Piercing-sucking mouth parts
  3) Plant symptoms - loss of plant vigor, yellow deformed foliage, leaf drop, give off honeydew
f) Fungus gnats and shore flies - insects
  1) Adult size - 1/8 inch (3 mm)
  2) Larvae, which are 1/4 inch (6 mm) long, have chewing mouth parts and feed on plants; adults do not feed on plants.
  3) Plant symptoms - lack of plant vigor, stunting, wilted leaves, leaf drop, yellow foliage
  4) Shore flies are slightly larger than fungus gnats, but have a very similar life cycle.
g) Scale - insects
  1) Adult size - 5/16 inch (8 mm)
    (a) Roundish, hard shells
    (b) Waxy or rubbery coatings - give off honeydew
  2) Piercing-sucking mouth parts
  3) Plant symptoms - lack of plant vigor, stunting, yellow leaves, leaf drop
h) Slugs and snails - mollusks
  1) Adult size - up to 4 inches (10 cm)
  2) Chewing mouth parts
  3) Plant symptoms - large holes in leaves, can completely defoliate a plant
  4) Snails have a hard shell, while slugs do not.

4. Discuss the three categories of plant diseases that affect greenhouse crops.

What are the three categories of plant diseases?

a) Diseases caused by living organisms

        1) Bacterial diseases (e.g., leaf spot of geranium)
        2) Fungal diseases (e.g., damping-off and botrytis of geranium)
        3) Nematode-caused diseases (e.g., soil nematodes and foliar nematodes)
    b) Diseases caused by viruses (e.g., Tomato spotted wilt virus and Cattleya orchid mosaic virus)
    c) Diseases caused by nonliving or physiological factors (e.g., air pollution damage)

5. Discuss the major diseases of greenhouse crops. If possible, show plants that have been damaged by each disease.

   What are the four major diseases of greenhouse crops?

   a) Damping-off - caused by Pythium, Phytophthora, and Rhizoctonia fungi
      1) Fungi originate on seed or in soil.
      2) Pre-emergence infection - Seed is destroyed by Pythium and Phytophthora fungi before it germinates or before shoot emerges from soil.
      3) Postemergence infection - Seedling is destroyed by Rhizoctonia fungus at soil level or upright seedlings become stunted and die.
   b) Botrytis or gray mold - caused by fungus
      1) Most costly disease of greenhouse crops
      2) Plant symptoms - gray spots on foliage, tissues underneath spots turn soft and then turn brown and rot
      3) Botrytis requires a cool, humid environment to grow.
   c) Foliar diseases (e.g., leaf spot) - caused by bacteria or fungi
      1) Plant symptoms - discolored leaves, distorted leaves
      2) If caused by bacteria, discard infected plant
      3) Apply fungicide to control foliar diseases caused by fungi.
      4) Low humidity helps to prevent fungal foliar diseases.
   d) Root rot disease - caused by bacteria or by Pythium and Phytophthora fungi
      1) Most common cause of houseplant death is root rot (Overwatering enables the bacteria and fungi to enter the root system.)
      2) Plant symptoms
         (a) Diseased roots are brown or black and few in number.
         (b) Roots look slimy and have a foul odor.
         (c) Plants have decreased uptake of water and dissolved nutrients by root hairs.
         (d) Foliage symptoms include yellow leaves, wilted leaves, and leaf drop.
   e) Disease identification procedures
      1) Contact local University Extension Center.
      2) Contact Extension Plant Pathology Laboratory at the University of Missouri-Columbia.

F. Other activities

Visit an entomology museum or a local insect collector to view preserved insect specimens, particularly the ones mentioned in this lesson.

G. Conclusion

Many pests and diseases affect plant growth in the greenhouse. Proper identification of plant pests and diseases is important in order to effectively prevent them from damaging floriculture crops.

H. Competency

Identify common pests and diseases found in Missouri greenhouses.

I. Answers to Evaluation

1. a
2. b

3. d
4. d
5. c
6. c
7. b
8. a
9. b
10. d
11. Diseases caused by living organisms
    Diseases caused by viruses
    Diseases caused by nonliving or pathological factors
12. Food source for sooty black mold fungus which decreases the plant's aesthetic beauty
13. head, thorax, abdomen

J. Answers to AS 19.1

Answers have been provided for the eight major greenhouse pests. See the following pages.

Common name: aphids or "plant lice"

Arachnid, insect, or mollusk: insect

Length of adult in mm or cm and inches: 1-3 mm (1/8 inch)

Type of mouth parts: piercing-sucking

Color of adult: green, red, yellow, brown, or black

Life span: 3 weeks

Preferred food source, if any: nearly every greenhouse-grown crop

Method(s) of entrance into greenhouse: fly

Description of crop damage caused: stunting and distortion of new shoots, spread bacterial and viral diseases, give off honeydew which is the food source for sooty black mold fungus which attracts ants, yellow spots

Pest control method(s): repeated and frequent applications of insecticide

Common name: whitefly

Arachnid, insect, or mollusk: insect

Length of adult in mm or cm and inches: 2 mm (1/16 inch)

Type of mouth parts: piercing-sucking

Color of adult: white

Life span: about 5 weeks

Preferred food source, if any: many greenhouse crops, especially mums, poinsettias, and bedding plants

Method(s) of entrance into greenhouse: fly

Description of crop damage caused: yellow spots on foliage, give off honeydew which attracts sooty black mold fungus, spread viral diseases between plants

Pest control method(s): repeated and frequent insecticide applications, trap crops such as fuchsias or lantanas, yellow boards or strips coated with a sticky substance to trap whiteflies

Common name: scale

Arachnid, insect, or mollusk: insect

Length of adult in mm or cm and inches: 8 mm (1/4 inch)

Type of mouth parts: piercing - sucking

Color of adult: white, gray, black, or brown

Life span: about 2-4 months

Preferred food source, if any: wide variety of plants

Method(s) of entrance into greenhouse: on infested plant material

Description of crop damage caused: lack of plant vigor, stunting, yellow leaves, leaf drop, some types of scale insects give off honeydew which attracts sooty black mold fungus

Pest control method(s): insecticidal sprays or systemic pesticides

Common name: slug and snail

Arachnid, insect, or mollusk: mollusk

Length of adult in mm or cm and inches: up to 10 cm (4 inches)

Type of mouth parts: chewing

Color of adult: gray, brown, or black

Life span: up to 1 year

Preferred food source, if any: any type of plant

Method(s) of entrance into greenhouse: in soil, on flats, and plants brought into greenhouse

Description of crop damage caused: chew leaves - may entirely defoliate a plant

Pest control method(s): molluscicide baits, shallow pans of beer will attract slugs and snails which may then be collected and disposed of

Common name: mealybug

Arachnid, insect, or mollusk: insect

Length of adult in mm or cm and inches: 3-4 mm (1/3 inch)

Type of mouth parts: piercing - sucking

Color of adult: white

Life span: 7-10 weeks

Preferred food source, if any: many greenhouse crops

Method(s) of entrance into greenhouse: males fly, wingless females are carried in

Description of crop damage caused: loss of plant vigor, yellow deformed foliage, leaf drop, give off honeydew which attracts sooty black mold fungus

Pest control method(s): repeated and frequent pesticide applications are needed. Because adults and eggs are covered with wax, aim the pesticide spray at the immature forms of this insect.

Common name: fungus gnat and shore fly

Arachnid, insect, or mollusk: insect

Length of adult in mm or cm and inches: 3 mm (1/8 inch); shore fly is larger

Type of mouth parts: larva - chewing; adults don't feed on plants

Color of adult: gray or black

Life span: about 1 month

Preferred food source, if any: many types of crop plants

Method(s) of entrance into greenhouse: soil, organic matter; shore fly eggs in peat moss

Description of crop damage caused: lack of plant vigor, stunting, wilted leaves, yellow foliage, leaf drop

Pest control method(s): insecticides aimed at larvae and adults, discourage fungus growth on and around plants

Common name: mite

Arachnid, insect, or mollusk: arachnid

Length of adult in mm or cm and inches: very small, about 0.50 mm (1/50 inch)

Type of mouth parts: piercing - sucking

Color of adult: colorless, red, or green

Life span: 2-4 weeks

Preferred food source, if any: nearly all plant species

Method(s) of entrance into greenhouse: on infested plant material

Description of crop damage caused: tiny yellow dots on foliage, curled leaves, bronze foliage, tiny webs among foliage cause leaves to turn brown

Pest control method(s): frequent and repeated applications of miticide are necessary

---

Common name: thrips

Arachnid, insect, or mollusk: insect

Length of adult in mm or cm and inches: about 1mm (1/25 inch)

Type of mouth parts: rasping - lapping

Color of adult: black, brown, or yellow

Life span: as little as 2 weeks

Preferred food source, if any: preferring tender buds, flowers, or axils of many plants

Method(s) of entrance into greenhouse: carried on wind

Description of crop damage caused: malformation of new growth, misshapen flowers, streaking and browning of flower petals, leaf and flower drop, carry viral diseases from plant to plant

Pest control method(s): frequent and repeated applications of insecticides, use very fine screening on all greenhouse vents and openings, locate vents perpendicular to prevailing winds

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Name ____________________

Lesson 19: Common Greenhouse Pests and Diseases

Date ____________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is the most common greenhouse insect pest?

   a. Green peach aphid
   b. Fungus plant
   c. Whitefly
   d. Mealybug

2. Which greenhouse pest or pests probably cause the most economic damage and are the most difficult to control?

   a. Fungus gnat
   b. Mite
   c. Slug and snail
   d. Mouse and rat

3. Which pest can be attracted by trap crops such as fuchsias?
   a. Thrips
   b. Scale insects
   c. Mealybugs
   d. Whiteflies

4. Which insect spreads bacterial and/or viral diseases from plant to plant?

   a. Aphids
   b. Whiteflies
   c. Thrips
   d. All of the above

5. Which insect has a rasping-lapping mouth type?

   a. Aphids
   b. Scale insects
   c. Thrips
   d. All of the above

6. Which of the following insects has egg clusters that look like a tiny bit of cotton fluff?

   a. Scale insect
   b. Whitefly
   c. Mealybug
   d. Thrips

7. Which part of the plant does the fungus gnat larvae damage?

   a. Leaves
   b. Roots
   c. Stems
   d. Flowers

8. "Pre-emergence infection" and "postemergence infection" refer to what type of fungal disease?

   a. Damping-off
   b. Botrytis
   c. Leaf spot
   d. Sooty black mold

9. Which of the following diseases is probably the most costly to greenhouse owners?

   a. Damping-off
   b. Botrytis
   c. Leaf Spot
   d. Sooty black mold

10. What is the most common cause of houseplant death?

   a. Viral diseases
   b. Insufficient fertilizer
   c. Insects
   d. Overwatering

Complete the following short answer questions.

11. List the three categories of plant diseases.

   a.
   b.
   c.

12. Aphids, whiteflies, mealybugs, and scale insects all give off honeydew. List one reason why the presence of honeydew is harmful to greenhouse-grown plants.

13. List the three major body parts of adult insects.

   a.
   b.
   c.

COMMON GREENHOUSE PESTS

AS 19.1

Common name: ____________________

Arachnid, insect, or mollusk: ____________________

Length of adult in mm or cm and inches: ____________________

Type of mouth parts: ____________________

Color of adult: ____________________

Life span: ____________________

Preferred food source, if any: ____________________

Method(s) of entrance into greenhouse: ____________________

Description of crop damage caused: ____________________

____

____

Pest control method(s): ____________________

____

____

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 20: Techniques and Equipment Used to Apply Pesticides

Objective: The student will be able to describe control methods, chemical formulations, and equipment used to control pests in the greenhouse.

Study Questions

1. **What are the target pests for the different types of pesticide?**
2. **What are the methods used to control plant pests?**
3. **What equipment is used to apply pesticides?**
4. **What are the different formulations of pesticides?**
5. **What is the mode of action for different types of pesticides?**
6. **Where can the greenhouse manager find up-to-date pesticide recommendations?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. U.S. Department of Agriculture and U.S. Environmental Protection Agency. Applying Pesticides Correctly, A Guide for Private and Commercial Applicators. U.S. Department of Agriculture and U.S. Environmental Protection Agency. (available from the Instructional Materials Laboratory, 2316 Industrial Drive, Columbia, MO 65202)

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 20: Techniques and Equipment Used to Apply Pesticides

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

It is important to identify the various methods used to control plant pests, as well as the various types of pesticide application equipment used in the commercial greenhouse. In addition, it is imperative to define pesticide formulations and to understand the mode of killing/repelling action for commercially used pesticides.

C. Assignment

D. Supervised study

E. Discussion

1. A multitude of pests cause problems in the commercial greenhouse, as well as in all of horticulture; therefore, it is important to know what type of pesticide to use on different pests.

What are the target pests for the different types of pesticide?

Type of Pesticide	Target Pest
acaricide	mites, ticks
bactericide	bacteria
fungicide	fungi
herbicide	weeds
insecticide	insects
miticide	mites
molluscicide	slugs, snails
nematicide	nematodes
rodenticide	mice, rats

2. Discuss with students various methods used to control plant pests. Point out to students that three goals should be kept in mind when planning for successful pest control. These goals are to protect the environment, select the best combination of pest control methods, and apply chemical pesticides only when necessary.

What are the methods used to control plant pests?

a) Chemical pesticides
    1) Quickest method to kill pests
    2) Most effective
    3) Only sure way to kill many pests
    4) Important to apply chemicals only when necessary and at the proper time in the pest's life cycle
    5) Always follow chemical pesticide label directions exactly
b) Cultural practices
    1) Used during the growing phase of floriculture crops
    2) Used to alter the environment, the condition of the host, or the behavior of the pest
    3) Examples of cultural practices

- (a) Grow trap crops (e.g., fuchsia) to attract insects.
  - (1) Treat trap crop with a systemic insecticide; pests feed and then die.
  - (2) Grow trap crop as preferred food source; discard trap plants and feeding insects together.
- (b) Vary the planting time.
- (c) Control greenhouse temperature and humidity levels.

c) Mechanical control measures
- 1) Stop spread of pests or kill pests
- 2) Mechanical control devices
  - (a) Screens - prevent entry when placed on windows and around heaters
  - (b) Pest traps (e.g., roach trap)
  - (c) Yellow sticky boards, cardboard, or tapes
    - (1) Coated with a sticky substance to which insects stick
    - (2) The color yellow attracts whiteflies and fungus gnats

d) Good sanitation practices
- 1) Remove weeds from under benches and around the exterior of the greenhouse structure.
- 2) Plant pest-free seeds and plant materials (e.g., cuttings and starter plants).
- 3) Prohibit tobacco use in the greenhouse to avoid spreading tobacco mosaic virus disease.
- 4) Tobacco users must wash their hands before touching plants to avoid disease spread.
- 5) Always keep the hose end off the floor to avoid spreading disease organisms from the floor to the entire crop.
- 6) Keep feet off of greenhouse benches.

e) Biological control
- 1) Use natural enemy to control plant pest (e.g., wasp that attacks and kills whiteflies).
- 2) Pest's enemy must be introduced to crop at regular intervals.
- 3) Natural enemies are expensive to purchase.
- 4) Total elimination of plant pest by biological control is difficult to accomplish.
- 5) Biological control is rarely used today, but may become more popular as chemical pesticides are taken off the market.

f) Natural genetic resistance to certain pests
- 1) African violets are not bothered by whiteflies.
- 2) Cacti are rarely attacked by pests.

2. Discuss with students the equipment used to apply pesticides. Provide examples of the different equipment.

What equipment is used to apply pesticides?

a) Hand-held sprayers
- 1) Used to apply limited quantities of pesticides
- 2) Advantages
  - (a) Easy to operate
  - (b) Inexpensive
  - (c) Easy to maintain
- 3) Disadvantages
  - (a) Pesticide must be shaken often, especially if a wettable powder formulation, in order to keep the pesticide in suspension.
  - (b) Hand-held sprayer pressure and output of pesticide will fluctuate.
  - (c) It is nearly impossible to apply exact quantities of pesticide using a hand-held sprayer.
- 4) Types of hand sprayers
  - (a) Pressurized can or aerosol bomb - contains less than one quart or one liter of pesticide solution
  - (b) Trigger pump sprayer - holds from one pint to one gallon of pesticide solution

- (c) Hose end sprayer device
  - (1) Container of pesticide concentrate holding up to one quart or one liter - attached to hose end
  - (2) Concentrate mixes with water coming through the hose
  - (3) Delivers a fixed rate of pesticide
  - (4) Hose siphon proportioner often used
  - (5) Delivers approximately 15 gallons of diluted pesticide solution before concentrate container needs refilling
- (d) Push-pull pump sprayer
  - (1) Push-pull pumping action applies pesticide to plants.
  - (2) It is ineffective in applying pesticide with force, thus hard to get adequate coverage of plants.
- (e) Hand pump compressed air sprayer
  - (1) Holds one to three gallons of pesticide solution
  - (2) Frequently used by small commercial greenhouses and homeowners

- b) Backpack sprayers - hold up to 5 gallons
- c) Wheelbarrow sprayers - sprayers mounted on wheels
  - 1) Used in larger commercial greenhouses
  - 2) Gasoline or electrically powered
  - 3) Offers great freedom of movement with 25 feet of hose
  - 4) Pesticide delivered under high pressure - good foliage coverage
  - 5) Available in many sizes and capacities of delivery
- d) Aerosol generators and foggers
  - 1) Fills entire greenhouse with pesticide fog or mist
  - 2) Types of aerosol generators or foggers
    - (a) Cold fogger - pesticide broken into mist particles by mechanical means
    - (b) Thermal generator or thermal fogger - uses heat to vaporize the pesticide

3. Discuss with students the different formulations of pesticides. Pesticides are available in various formulations or preparations. Explain to students the difference between active ingredients (i.e., killing agents) and inert ingredients (i.e., agents which carry the active ingredients and which facilitate their application).

What are the different formulations of pesticides?

- a) Liquid formulations
  - 1) Aerosols (denoted by the letter "A" on the label) - usually sold in pressurized cans or aerosol bombs
  - 2) Emulsifiable concentrates (denoted by the letters "EC" on the label) - mix with water in the spray tank
  - 3) Encapsulated insecticides
    - (a) Contain pesticide sealed in tiny microcapsules
    - (b) Usually packaged in a 16-ounce aerosol can
    - (c) Timed release of pesticide over a two-week period
  - 4) Flowable insecticides (denoted by the letter "F" or "L" on the label)
    - (a) Readily poured
    - (b) Easily mixed with water
    - (c) Easily measured
    - (d) They create no dust because they are liquid, hence they are safer to handle.
- b) Dry formulations
  - 1) Bait (denoted by the letter "B" on the label)
    - (a) Contains a pesticide-laden food or other substance attractive to pests
    - (b) Often used to kill slugs, snails, and rodents
  - 2) Dust (denoted by the letter "D" on the label)
    - (a) Pesticide and inert ingredients ground into a fine dust
    - (b) Applied without the addition of water
  - 3) Granular (denoted by the letter "G" on the label)
    - (a) Prepared like a dust
    - (b) Bigger particles than dust particles

    (c) Applied without the addition of water
  4) Soluble powder (denoted by the letters "S" or "SP" on the label)
  5) Wettable powder (denoted by the letters "W" or "WP" on the label)
    (a) Mixes with water in the spray tank
    (b) Once mixed, constant agitation needed to keep pesticide in suspension
  6) Dry flowable
    (a) Dry granules of pesticide that are easily poured
    (b) Create no dust, therefore safer to use than powders

4. Discuss with students the mode of action for different types of pesticides. Point out the location of this information on the container label. Many pesticides work in more than one way.

What is the mode of action for different types of pesticides?

a) Biologicals - contain living organisms (e.g., viruses, bacteria, and fungi) that cause the pest to become diseased and die
b) Contact pesticides - kill pests on contact
c) Fumigants - poison gases that the pest breathes or absorbs
d) Growth regulators - cause insect development to be adversely affected
e) Nonselective herbicides - kill all plants
f) Pheromones - natural chemical that attract pests is used to lure pests into a trap
g) Protectants - prevent the entry or damage by pests
h) Selective herbicides - kill only target weeds
i) Sterilants - treated pests unable to reproduce
j) Stomach poison pesticides - kill when eaten or swallowed
k) Systemics - absorbed by plant and then translocated by the vascular system to all its parts; after a pest feeds on a plant treated with a systemic, it dies

5. Discuss with students where the greenhouse manager can get information regarding current recommended pesticides for use in the greenhouse. Since pesticide recommendations change frequently, it is important for the greenhouse manager to be up-to-date.

Where can the greenhouse manager find up-to-date pesticide recommendations?

a) University Extension - check with local office
b) Pesticide dealers
c) Missouri Department of Agriculture

F. Other activities

1. Visit a commercial greenhouse to examine its pesticide application equipment.

2. Show the slide set Greenhouse Safety by David Jennings, from Cornell University Instructional Materials Services, Ithaca, N.Y.

3. Show the video Pesticide Safety in the Greenhouse by the Idea Bank, available from the Missouri Vocational Resource Center, 10 London Hall, Columbia, MO 65211.

G. Conclusion

When controlling pests the greenhouse manager should remember to protect the environment, select the best combination of pest control methods, and apply chemical pesticides only when necessary. Although there are many methods available to control pest populations, the most commonly-used method in the commercial greenhouse is chemical pesticides. Whenever handling or applying any pesticide, always follow pesticide label instructions exactly.

H. Competency

Describe control methods, chemical formulations, and equipment used to control pests in the greenhouse.

I. Answers to Evaluation

1. b
2. c
3. a
4. d
5. c
6. a
7. a. Protection of the environment as much as possible
   b. Selection of the best combination of pest control methods, based upon the kind and amount of control desired
   c. Application of chemical pesticides only when necessary - Always follow label directions exactly.
8. Any two of the following:
   a. University of Missouri Extension Division
   b. Pesticide dealers
   c. Missouri State Department of Agriculture
9. Any three of the following:
   a. Remove weeds from under greenhouse benches and around the greenhouse.
   b. Plant pest-free seeds and plant materials.
   c. Prohibit tobacco use in the greenhouse.
   d. Tobacco users must wash their hands before touching plants.
   e. Always keep the hose end off of the greenhouse floor.
   f. Keep feet off greenhouse benches.
10. a. Active ingredients are the killing agents.
    b. Inert ingredients are agents which carry the active ingredients and facilitate their application.

UNIT - GREENHOUSE OPERATIONS AND MANAGEMENT

Name____________________

Lesson 20: Techniques and Equipment Used to Apply Pesticides

Date____________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following pesticide formulations is absorbed by the treated plant and translocated to all its parts?

   a. Contact
   b. Systemic
   c. Pheromone
   d. Fumigant

2. Which of the following pest control measures is seldom used in the commercial greenhouse?

   a. Mechanical methods
   b. Cultural or growing practices
   c. Biological control
   d. Chemical pesticides

3. A pot of fuchsia growing in the greenhouse as a trap plant for whitefly control, would be what type of pest control practice?

   a. Cultural control
   b. Chemical control
   c. Biological control
   d. Mechanical control

4. What is the quickest and most effective tactic against pests in the commercial greenhouse?

   a. Fly swatter
   b. Natural enemies
   c. Proper sanitation
   d. Chemicals

5. What is the most commonly used hand-held sprayer in the small commercial greenhouse?

   a. Pressurized sprayer can
   b. Hose end sprayer device
   c. Compressed air sprayer
   d. Trigger pump sprayer

6. Which of the following is not a liquid pesticide formulation?

   a. Granular concentrate
   b. Flowable insecticide
   c. Emulsifiable concentrate
   d. Encapsulated insecticide

Complete the following short answer questions.

7. List the three main goals to consider when choosing a pest control method(s).

   a.

   b.

   c.

8. List two sources to contact for information about current pesticide recommendations.

   a.

   b.

9. List three ways to practice good sanitation in the greenhouse in order to prevent the spread of pests, including disease organisms.

   a.

   b.

   c.

10. Briefly define the following pesticide terms:

    a. active ingredients

    b. inert ingredients

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 21: Pesticide Safety

Objective: The student will be able to identify safety guidelines for pesticide use.

Study Questions

1. **How is pesticide toxicity measured?**
2. **What information is located on a pesticide label?**
3. **What are symptoms of pesticide poisoning?**
4. **What are the correct first aid procedures for pesticide poisoning?**
5. **Where is the nearest poison control center?**
6. **What supplies should be included in a first aid kit?**
7. **What are the safety guidelines for using pesticides?**
8. **What are the safe ways to dispose of pesticides and pesticide containers?**
9. **What certifications are required for pesticide applicators?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. University Extension agricultural publications:
    a) G01915: First Aid for Pesticide Poisoning
    b) G01916: Pesticide Application Safety
    c) G01917: Personal Protective Equipment for Working with Pesticides
    d) G01918: Homeowner Chemical Safety

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 21: Pesticide Safety

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

Since most pesticides are toxic to humans, animals, and/or the environment, it is important for pesticide applicators to read and follow label directions exactly. Federal and state laws mandate how pesticides should be applied and on what they can be applied.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with students how pesticide toxicity is measured. Discuss with students why it is important to measure the toxicity level of pesticides.

How is pesticide toxicity measured?

By the classic LD50 test
- a) "LD" stands for the "lethal dose" of the pesticide, expressed in milligrams of pesticide per kilogram of animal body weight, necessary to kill half of the test animals within two weeks.
- b) The lower the LD number, the greater the pesticide toxicity and the less it takes to kill.

2. Discuss with students the information found on a pesticide label. The instructor may want to point out the information on several pesticide labels.

What information can be found on a pesticide label?

- a) Signal words - located directly below the "Keep Out Of The Reach Of Children" statement; based on the pesticide toxicity level
  - 1) Class I. DANGER or DANGER-POISON with an accompanying drawing of a skull and crossbones
    - a) Letters printed in red
    - b) Highly toxic category
    - c) Oral LD50 rating of 0 - 50
  - 2) Class II. WARNING
    - a) Moderately toxic category
    - b) Oral LD50 rating of 50 - 500
  - 3) Class II. CAUTION
    - a) Slightly toxic category
    - b) Oral LD50 rating of 500 - 5,000
- b) Type of pesticide
- c) Directions for application
- d) Target pest(s)
- e) Plants on which pesticide may be applied
- f) Disposal methods
- g) First aid procedures

3. Discuss with students the symptoms of pesticide poisoning. Point out that there are no standard symptoms.

   What are symptoms of pesticide poisoning?

   a) No standard symptoms of pesticide poisoning - Symptoms vary depending on several factors.
      1) Kind and amount of pesticide
      2) Length of exposure
      3) Time interval between exposures
      4) Victim's general health
   b) Two categories of pesticide poisoning - Many pesticides fit in both categories.
      1) External irritants - e.g., stinging of nose, eyes, ears, throat, and mouth due to pesticide splashing on external tissues
      2) Internal poisons - e.g., injury to body organs due to pesticide being taken into the body through the mouth or skin

4. Discuss with students the correct first aid procedures for pesticide poisoning. More first aid information can be found in the MU guide #G01915, "First Aid for Pesticide Poisoning."

   What are the correct first aid procedures for pesticide poisoning?

   a) Act as quickly as possible.
   b) Without endangering yourself, remove the victim from the contaminated area.
   c) Remove contaminated clothing from the victim.
   d) Generously flood the affected skin area or eye with water.
   e) Contact the Poison Control Center or a doctor.
   f) Administer first aid as indicated by Poison Control Center Personnel or doctor.

   NOTE: If a pesticide accident occurs at school, the instructor should notify the school nurse as soon as possible.

5. Discuss with students information about the nearest poison control center. The instructor should post the toll-free number by the telephone, so it is handy in the event of pesticide poisoning.

   Where is the nearest poison control center?

   a) Missouri's center is staffed 24 hours by medical professionals.
      Missouri Regional Poison Control Center
      Cardinal Glennon Memorial Hospital
      1465 South Grand Avenue
      St. Louis, Missouri 63104
      Telephone: **1-800-392-9111**
   b) It is important to have the pesticide label when talking with the Poison Control Center.

6. Discuss with students the importance of having a first aid kit available.

   What supplies should be included in a first aid kit?

   a) Adhesive tape
   b) Assorted bandages
   c) Blanket
   d) Merthiolate
   e) Syrup of ipecac
   f) Teaspoon
   g) Two quarters (for phone calls)

   NOTE: It is crucial that the school greenhouse have a complete first aid kit available. Poison Control Center personnel or a doctor will indicate first aid procedures that need to be followed.

7. Discuss with students safety guidelines for using pesticides. Emphasize how important it is to read and follow all pesticide label directions. More information can be found in University Extension guide #G01917, "Personal Protective Equipment for Working with Pesticides."

What are the safety guidelines for using pesticides?

a) Always read and follow label directions exactly.
  1) Application directions
  2) Preharvest interval
  3) Re-entry time
b) Remove all people, pets, and foodstuffs prior to pesticide application.
c) Close all doors, vents, and openings in the greenhouse before applying pesticides in order to avoid pesticide drift.
d) Never smoke, eat, or drink while applying pesticides.
e) Always wear protective clothing and use protective equipment to prevent exposure to external irritant pesticides.
  1) Long trousers and long-sleeved shirt or coveralls - clean
  2) Eye goggles or a face shield
  3) Rubber gloves - unlined neoprene gloves covering the wrists
  4) Unlined rubber boots made of neoprene
  5) Wide-brimmed waterproof hat
f) Always wear a respiratory device approved by NIOSH and MSHA to prevent internal poisoning.
  1) Cartridge respirator
    (a) Used in combination with eye goggles
    (b) Air drawn through fiber filter and charcoal cartridge
    (c) Satisfactory for occasional exposure to most pesticides
  2) Gas mask (canister) respirator
    (a) Gas mask covering the entire face with a built-in shield to protect eyes
    (b) Longer lasting absorbent filters
    (c) Greater filtering capability than a cartridge respirator
    (d) For prolonged exposure to pesticides
    (e) For exposure to high pesticide concentrations

NOTE: Discard used cartridge, canister, or filter if experiencing trouble breathing normally or if smelling pesticide odor.

  3) Positive pressure respirator
    (a) Available as a backpack
    (b) Blower draws pesticide laden air through a filter and then forces the purified air into an airtight helmet covering the entire head
  4) Self-contained breathing apparatus
    (a) Similar to a supplied-air respirator
    (b) Applicator carries air tanks, usually on his/her back
    (c) Use when pesticide vapor concentration is high (e.g., when using a fumigant pesticide)
g) Shower and shampoo after applying pesticides.
h) Launder pesticide-laden clothing separately from other clothing or dispose of properly, if disposable.
i) Maintain a health surveillance program with a physician if applying pesticides on a regular basis.
  1) Inform the doctor of the exact pesticides used so he or she can review chemical formulations and stock a supply of antidotes.
  2) Follow procedures for applicators of carbamate or organophosphate insecticides.
    (a) Regular cholinesterase testing program with doctor
    (b) "Baseline" test taken in January
    (c) Periodic retests for cholinesterase level - If cholinesterase level falls too low, the doctor will limit or stop applicator's contact with these two insecticides until level returns to normal range.

8. Discuss with students the safe ways to dispose of pesticides and pesticide containers. More information can be found in the MU guide #G01916, "Pesticide Application Safety."

What are the safe ways to dispose of pesticides and pesticide containers?

a) Read and follow pesticide container label for disposal instructions and/or precautions.
b) Apply any surplus pesticide to other areas with the same pest problem.
c) Never flush pesticides down the drain, into sewers, or into waterways.
d) Take unwanted pesticides and/or pesticide containers to a toxic waste disposal landfill.
f) Follow these general guidelines for pesticide disposal as mandated by the U.S. Department of Agriculture and the U.S. Environmental Protection Agency.
    1) Never leave surplus pesticides and/or pesticide containers at the application site.
    2) Never reuse pesticide containers.
    3) Keep all pesticide containers out of the reach of children.
    4) Store leftover pesticides in tightly covered containers in a safe storage facility until they can be disposed.
g) For help with safe disposal of pesticides and/or pesticide containers, contact:

Missouri Department of Natural Resources
Division of Environmental Quality
P.O. Box 176
Jefferson City, Missouri 65102
Business phone: 314-751-7929
Emergency response phone: 314-634-2436

9. Discuss with students the certifications required for pesticide applicators.

What certifications are required for pesticide applicators?

a) Two classifications of pesticides exist relative to legalities surrounding their application - Some pesticides may be a combination of the two.
    1) "General use" pesticides not likely to harm people, wildlife, and/or the environment when used according to label directions.
        (a) Examples are Malathion®, Talstar®, and Benlate®.
        (b) Certification is not required.
    2) "Restricted use" pesticides could cause serious injury to people, wildlife, or the environment unless applied by a well-trained and competent pesticide applicator, or under the direct supervision of such an applicator.
        (a) Examples are Lannate®, Vydate®, and Di-Syston®.
        (b) Certification is required.
b) Two main categories of certified pesticide applicator's licenses
    1) Private applicator
        (a) Administer restricted use pesticides onto their own land or onto land they rent, or onto property of a person with whom they trade services
        (b) Receive training in pesticide application
        (c) Common type of license for most horticulturists
        (d) License valid for five years and then must be renewed
    2) Commercial applicator
        (a) Administer restricted use pesticides for hire onto the property of others
        (b) Receive training similar to private applicator training
        (c) Receive additional instruction in various areas of pesticide application specialization
        (d) License valid for three years and then must be renewed

NOTE: To obtain certification, the applicant must undergo instruction through the University of Missouri-Columbia Extension Division. The State of Missouri Department of Agriculture Plant Industries Division sets up the instruction, and the EPA oversees Missouri's certification program.

F. Other activities

1. Visit a local greenhouse to see their pesticide application equipment, including respirators and protective clothing. Require students to take notes on their observations. Ask students to prepare a written report on the field trip.

2. Show the audiovisual materials for private pesticide applicator's license from University Extension.

3. Ask students to participate in the training session required to gain a private pesticide applicator's license.

4. Invite an extension agent to talk about pesticide safety.

5. Have students write to one of the following for more information about pesticides.

   a) Occupational Safety and Health Administration (OSHA)
   Regional Office: 911 Walnut St.
   Kansas City, Mo 64106
   Telephone - 816-374-5861
   St. Louis Office: 4300 Goodfellow
   St. Louis, MO 63120
   Telephone - 314-263-2749
   Nationwide toll-free telephone - 1-800-392-7743

   b) National Institute for Occupational Safety and Health (NIOSH)
   200 Independence Avenue SW
   Washington, D.C. 20201
   Telephone - 202-472-7134

   c) Mine Safety and Health Administration (MSHA)
   4015 Wilson Blvd.
   Arlington, VA 22203
   Telephone - 703-235-1385

G. Conclusion

Pesticide applicators must know and practice the principles of safe pesticide use in order to protect themselves, domestic animals, wildlife, and/or the environment from the effects of toxic pesticides. Always read and follow all pesticide label directions.

H. Competency

Identify safety guidelines for pesticide use.

I. Answers to Evaluation

1. b
2. c
3. d
4. d
5. a
6. d
7. a

8. A general use pesticide is not likely to harm people, wildlife, and/or the environment when used according to label directions. A restricted use pesticide could cause serious injury to people, wildlife, and/or the environment.
9. No, general use pesticides do not require certification.

10. Leave the pesticide application area immediately. Generously flush contaminated area with water. Call the Poison Control Center for further first aid instructions, if the pesticide was in the "danger" or "warning" toxicity category.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name________________

Lesson 21: Pesticide Safety Date________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is the most important thing to remember when working with pesticides?

   a. Wear protective clothing.
   b. Read and follow label directions.
   c. Close all doors and windows in the greenhouse.
   d. Apply pesticides only when needed.

2. Which signal word or words represent the slightly toxic pesticide category?

   a. WARNING
   b. DANGER
   c. CAUTION
   d. DANGER-POISON

3. What are the standard symptoms of pesticide poisoning?

   a. Headache, vomiting, and rash
   b. Headache, rash, and redness
   c. Headache, rash, and diarrhea
   d. No standard symptoms

4. What is the most important rule when applying first aid to a pesticide poisoning victim?

   a. Induce vomiting
   b. Check for shock symptoms
   c. Remove contaminated clothing
   d. Act immediately to begin first aid procedures

5. Which of the following would be adequate when applying most pesticides on an occasional basis?

   a. Cartridge respirator
   b. Gas mask (canister) respirator
   c. Self-container breathing device
   d. Positive pressure respirator

6. The Missouri Regional Poison Control Center is located at the Cardinal Glennon Memorial Hospital in what city? The toll-free telephone number is 1-800-392-9111.

   a. Jefferson City
   b. Kansas City
   c. Springfield
   d. St. Louis

7. Which type of certified pesticide applicator's license would most horticulturists, including greenhouse operators, hold?

   a. Commercial
   b. Private
   c. General use
   d. They do not need a license.

Complete the following short answer questions.

8. Explain the difference between a "general use" pesticide and a "restricted use" pesticide.

9. You want to apply "general use" pesticides on your vegetable garden. Do you need to be certified? Why or why not?

10. You are spraying pesticide in a greenhouse when your rubber glove is ripped on a bench as you go by. You immediately feel moisture on your hand. What should you do?

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 22: Marketing Floricultural Crops

Objective: The student will be able to prepare a plant for sale.

Study Questions

1. **What are potential markets for greenhouse crops?**
2. **How can the quality of floricultural crops be maintained during the marketing process?**
3. **What steps should be followed to prepare a plant for sale?**

References

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.
2. Job Sheet
    a) JS 22.1: Preparing a Potted Plant for Sale

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 22: Marketing Floricultural Crops

TEACHING PROCEDURES

A. Introduction

B. Motivation

Ask students if they like to make money. How would they go about selling their plants growing in their greenhouse? For a grower to earn a profit, it is necessary to know how to grow plants, market plants, and make them last a long time.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss potential markets in the local community. The following questions only give possible markets not necessary all markets available. Discuss the advantages and disadvantages of wholesale and retail markets.

What are potential markets for greenhouse crops?

a) Wholesale - selling to businesses that will re-sell the plants (e.g., wholesalers, local grocery stores, local florists, chain department stores, hardware stores, local organizations)
    1) Advantages
        (a) Usually can sell the entire crop all at one time
        (b) No need to hire salespeople
        (c) Don't have to wait on customers, worry about liability of people running through your greenhouse, etc.
        (d) No expenditure for advertising
        (e) Not necessary to be open for business for longer hours, weekends
        (f) Don't have to deal with customers' complaints
    2) Disadvantages
        (a) Lower return per crop unit
        (b) Additional equipment (e.g., deliver vehicles) needed
        (c) Marketing may be more competitive due to other greenhouses shipping plants into market area.

b) Retail - selling to the people that will be using the plants (e.g., retail greenhouse, farmers' market)
    1) Advantages
        (a) Higher return per crop unit
        (b) May develop more reliable market due to repeat customers
        (c) Do not need certain marketing equipment (e.g., large delivery vehicles)
        (d) Personal reward from seeing customer satisfaction
    2) Disadvantages
        (a) Greenhouse needs to be designed to accommodate customers - lower benching efficiency
        (b) Support facilities (e.g., parking) required
        (c) More labor intensive - additional sales help needed
        (d) Competition from low-priced products in mass marketing outlets (e.g., chain stores) may jeopardize operation

c) Both wholesale and retail

2. Discuss steps that should be taken to ensure longevity in the consumer's home environment.

How can the quality of floricultural crops be maintained during the marketing process?

a) Poinsettias
  1) Harvest plants when mature (full color development).
  2) Plants should be thoroughly watered before shipping.
  3) If plants must be held prior to shipping, hold unsleeved and/or unboxed in the greenhouse or other well-lighted area between 50°F (10°C) and 75°F (24°C).
  4) Protect plants during shipping using boxes and plastic sleeves.
  5) Avoid extreme temperatures. Temperatures above 75°F (24°C) or below 50°F (10°C) during shipping and marketing shorten post-production life.
  6) Careful handling is required to prevent plant breakage.
  7) Avoid exposure to ethylene or other gases which may be harmful to the plant.
  8) During shipping, keep bracts dry to reduce the possibility of botrytis (gray mold).
  9) When received by the retailer, plants should be unpacked as soon as possible to reduce or prevent epinasty (droopiness). Poinsettias are especially susceptible to this condition.
  10) Display plants in a well-lighted area between 50° (10°C) and 75°F (24°C) away from hot and cold drafts.

b) Chrysanthemums
  1) Harvest when mature (1/2 to fully open).
  2) Remove from packing box immediately upon arrival and water the plant thoroughly.
  3) Remove all broken stems and blooms.
  4) Be sure that the mum is displayed with plenty of room so that it receives the best amount of light.
  5) Keep the plant out of direct sun.
  6) Make sure that it does not sit in a hot or cold draft.
  7) Do not keep the plant too wet - allow it to dry out between waterings but not to the wilting point.

c) Easter lilies
  1) Drop temperature if lilies start to bloom too soon.
  2) If necessary, lilies can be held in the dark at 35°F (2°C) to 45°F (7°C) for 20 days, when the buds are white and puffy. The soil should be kept moist and a fungicide should be applied as a drench 10 days before the lilies are put into storage.

d) Bedding plants
  1) May want to water stress plants a few days before they are sold.
  2) Do not allow the plants to wilt too much.
  3) Drop the temperature to 55°F (13°C) the last several weeks.
  4) Fertilizer is also reduced and in some cases, eliminated entirely in the last several weeks before sale.

3. Discuss the importance of preparing plants for sale. Ask students what would happen if they took a poinsettia without protection outside when the temperature is below freezing. Have students complete JS 22.1. The instructor may need to demonstrate the procedure before the students complete the task.

What steps should be followed to prepare a plant for sale?

1) Groom plant; remove yellow or dying leaves and old flowers.
2) Clean outside of pot.
3) Check plant for insects.
4) Insert care tag.
5) Water and drain the plant well.
6) Dress plant.

F. Other activities

1. Visit a local farmers' market, wholesale house, or roadside market.
2. Have students list all the local places where a grower could market a greenhouse crop.

G. Conclusion

Greenhouse growers need to know how they will market their crop if they are to make a profit and stay in business. Every grower must know how to handle a crop to ensure its lasting quality to satisfy consumers. Preparing a plant for sale will ensure that the plant will be the most attractive it can be and thus ensure its salability.

H. Competency

Prepare a plant for sale.

I. Answers to Evaluation

1. b
2. a
3. b
4. a. Groom plant; remove yellow or dying leaves and old flowers.
   b. Clean outside of pot.
   c. Check plant for insects.
   d. Insert care tag.
   e. Water and drain the plant well.
   f. Dress plant.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ____________________

Lesson 22: Marketing Floricultural Crops Date ______ ____________

Evaluation

Circle the letter that corresponds to the best answer.

1. What is the main advantage of selling at the retail level?

   a. The owner saves on advertising expenses.
   b. The owner receives a higher return per unit.
   c. The owner must provide parking for customers.
   d. The owner must have large delivery vehicles.

2. Which of the following is an advantage of a wholesale greenhouse business?

   a. The owner maximizes bench space.
   b. The owner works with customers on a daily basis.
   c. The owner must hire salespeople to handle customers.
   d. The owner must frequently work on weekends to meet customer demand.

3. Which of the following is not an example of a wholesale outlet for greenhouse owners?

   a. Hardware store
   b. Farmers' market
   c. Local grocery stores
   d. Local organizations

Complete the following short answer question.

4. What steps should be followed to prepare a plant for sale.

   a.

   b.

   c.

   d.

   e.

   f.

Job Sheet 22.1: Preparing a Potted Plant for Sale

Objective: The student will be able to prepare a potted plant for sale.

Materials

1. Potted plant - type to be determined by instructor
2. Care tag with appropriate information for plant
3. Foil
4. Ribbon
5. Scissors
6. Florists' wired wooden pick

Procedure

1. Groom plant; remove yellow or dying leaves and old flowers.

2. Clean outside of pot.

3. Check plant for insects.

4. Insert care tag.

5. Water and drain the plant well.

6. Dress plant.

   a. Cut foil appropriate size for pot. (about 26" for a 6-inch pot)

   b. With the best side of the plant toward you, place the pot on foil. It should be centered left and right, but slightly toward the front. Make sure the front of the foil will cover the front of the pot.

   c. With your left hand, work around the left side of the plant, gently gathering the foil up and around the pot. With your right hand, gently pull the corners upward as you work around the pot.

   d. After you have gathered the foil around the pot, curve the two front corners downward so that they form a frame around the front of the plant.

   e. Make a bow and tie it off with a wired wooden pick.

   f. Insert the pick into the growing medium.

   g. Protect the plant, if outside temperature is less than 40°F.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 23: Record Keeping in Greenhouse Management

Objective: The student will be able to describe various greenhouse records.

Study Questions

1. **What are cultural records?**
2. **What are environmental records?**
3. **What is a crop rotation plan?**
4. **What are cost accounting records?**

Reference

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 23: Record Keeping in Greenhouse Management

TEACHING PROCEDURES

A. Review

Review previous lesson.

B. Motivation

The production of flower crops is a competitive business. Any business that expects to be successful in a competitive environment must keep accurate records, for records help prevent businesses from making the same mistakes over and over. Financial records can aid the greenhouse manager in the decision-making process by identifying those crops that are the most profitable versus those that might actually be losing money. Finally, records are needed for legal reasons such as paying taxes.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with students the various types of records kept in greenhouse management.

What are cultural records?

a) Provide basis for duplicating a successful crop
b) List all the operations to be performed on the crop and target dates
    1) Planting
    2) Spacing
    3) Day length treatment
    4) Fertilizing
    5) Pest control
    6) Growth regulators
    7) Other cultural procedures
    8) Harvest
c) Kept at location of crop with duplicate in manager's office
d) Updated at the end of each working day
e) Filed in manager's permanent record after crop is harvested

2. Discuss environmental factors that affect crop growth. Point out how a week of cloudy days may affect the quality of the crops.

What are environmental records?

a) Provides record of environment in which plants were grown
    1) Inside temperature - Monitors climate control equipment
    2) Outside temperature
        (a) Available from National Weather Service
        (b) Helps allocate heating costs when cost accounting
    3) Solar radiation
        (a) Available from National Weather Service
        (b) Helps pinpoint environmental factors limiting plant growth
    4) Growing media nutrient analysis
        (a) Performed by private labs or industry-sponsored labs
        (b) Helps in diagnosis of nutritional problems

        - (c) Repeated periodically
    - 5) Foliar analysis
        - (a) Performed by private labs or industry-sponsored labs
        - (b) Valuable for solving nutritional problems
        - (c) Repeated periodically
    - 6) Insect and disease outbreak
        - (a) Helps evaluate control measures
        - (b) Gives indication of adjustments needed for next crops
        - (c) May explain poor crop quality
    - 7) Visual observations
        - (a) Notes of importance that do not fit above categories (e.g., pesticide phytotoxicity)
        - (b) Useful in improving next crop (e.g., change spray application technique to eliminate phytotoxicity)
- b) Kept in permanent record file of greenhouse manager

3. Discuss the importance of a crop rotation plan. Point out that greenhouse managers cannot afford to have part of the greenhouse empty, because overhead costs continue.

What is a crop rotation plan?

- a) Used to maximize profits by optimizing space utilization
    - 1) Important to occupy all space with profitable plants
    - 2) Costly vacant space
        - (a) Overhead costs continue
        - (b) No return from crop sales
- b) Contains cropping schedule to be followed throughout year
    - 1) Crops to be grown
    - 2) Amount of space allocated for each crop
    - 3) Location of each crop in greenhouse
- c) Coincide need for space with crop harvest
    - 1) Plant new crop
    - 2) Progressive spacing of established crop
- d) Computer program available to make development of crop rotation plans easier

4. Discuss cost accounting with the students. Explain the difference between fixed and variable costs.

What are cost accounting records?

They keep track of costs versus return on a crop.

- a) Fixed costs (overhead costs) - incurred by entire greenhouse not just one crop; incurred if greenhouse is full or empty; somewhat stable from year to year
    - 1) Depreciation
    - 2) Taxes
    - 3) Insurance
    - 4) Interest
    - 5) Repairs and maintenance
    - 6) Miscellaneous (e.g., salaries of managers, dues, accounting fees)
- b) Variable costs (direct costs) - incurred because the greenhouse is operating; may vary with the crop, season, or year
    - 1) Plant material - includes seed
    - 2) Cultural supplies (e.g., growing media, fertilizers, pesticides)
    - 3) Labor
    - 4) Fuel
    - 5) Utilities
    - 6) Sales costs (e.g., advertising and marketing expenses)
    - 7) Miscellaneous
- c) Income - represents income from crop; the following recorded for each crop

    1) Date of sale
    2) Market outlet - customer
    3) Product grade
    4) Number of units sold and price per unit
    5) Total sale
    4) "Dumpage" - separated into good but unwanted plants versus poor and unsalable plants

  d) Profitability - Determine profitability by preparing a cost analysis statement, which shows net return of crop.
    1) Fixed expenses - usually based on the average cost per week per square foot of bench space (including vacant bench space); formula follows:

       Total fixed costs + 52 + sq ft bench space = average cost/week/sq ft

    2) Variable expenses - assigned directly to crop as incurred by crop
    3) Income - returns for the crop
    4) Profit or loss - dollars remaining after total expenses

F. Other activities

1. Visit a local greenhouse. Ask the manager how he or she uses records to improve the business. Request to see a sample of the cultural records that are kept by the greenhouse.

2. Have students prepare a cultural record for a crop (e.g., poinsettia) that the class has studied or grown.

3. Obtain a computer software program designed for planning crop rotation schedules and demonstrate how it is used. Point out to students how laborious it is to perform the same task by hand.

G. Conclusion

By becoming acquainted with the various types of records kept in greenhouse management, students will have a greater understanding of the importance of record keeping. Additionally, they will see that a greenhouse manager must have a mind for business as well as being skilled in growing plants.

H. Competency

Describe the various types of records kept in a greenhouse business.

I. Answers to Evaluation

1. b
2. d
3. b
4. a
5. a
6. d
7. a
8. c
9. d
10. c
11. c
12. a
13. d
14. d
15. c

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ____________

Lesson 23: Record Keeping in Greenhouse Management Date ____________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Why are cultural records kept?
   - a. Satisfy the Internal Revenue Service
   - b. Duplicate a successful crop
   - c. Determine the profitability of a crop
   - d. All of the above

2. Which of the following would not be included on a cultural schedule?
   - a. Planting date
   - b. Fertilizing regime
   - c. Day length control
   - d. Fuel consumption

3. A cultural record should be kept for which of the following?
   - a. Plant
   - b. Crop of plants
   - c. Greenhouse unit
   - d. Greenhouse range

4. How often should the greenhouse manager verify entries on the cultural record sheet?
   - a. Daily
   - b. Twice weekly
   - c. Weekly
   - d. Twice monthly

5. Which of the following would not be found on an environmental record?
   - a. Planting date
   - b. Foliar analysis
   - c. Outside temperature
   - d. Available sunlight

6. How can environmental records help the greenhouse manager?
   - a. Monitor climate control equipment
   - b. Determine the cause of a poor crop
   - c. Determine which environmental factor is limiting growth
   - d. All of the above

7. How can growing medium and foliar analyses help?
   - a. Pinpoint nutritional problems
   - b. Prevent disease infestation
   - c. Monitor day length manipulation
   - d. Increase production time

8. Which of the following is not included on a crop rotation plan?

   a. Crops to be grown
   b. Location of crops in the greenhouse
   c. Market outlet for each crop
   d. Space assignment for each crop

9. What is the purpose of a crop rotation plan?

   a. To reduce insect infestations by keeping part of the greenhouse vacant
   b. To minimize heating costs
   c. To maximize plant density
   d. To optimize space utilization efficiency

10. Which of the following is not a fixed cost?

    a. Insurance
    b. Depreciation
    c. Fuel
    d. Interest on loans

11. Which is true concerning fixed costs?

    a. Vary widely from year to year
    b. Are incurred only when the greenhouse is in operation
    c. Are incurred by the entire greenhouse not by one crop
    d. None of the above

12. Which of the following is not a variable cost?

    a. Management salaries
    b. Plant material
    c. Utilities
    d. Advertising

13. Which is true concerning variable costs?

    a. Are the same from year to year
    b. Are assigned equally to each crop
    c. Are less obvious than fixed costs
    d. Occur only when the greenhouse is actually operating

14. Which of the following is not usually included on sales records?

    a. Date of sale
    b. Product grade
    c. Market outlet
    d. Shipping costs

15. How is the profitability of a crop determined?

    a. By adding direct and overhead costs
    b. By subtracting income from direct and overhead costs
    c. By subtracting direct and overhead costs from income
    d. None of the above

UNIT - GREENHOUSE OPERATION AND MANAGEMENT

Lesson 24: Legal Considerations

Objective: The student will be able to describe the relevance of the United States Plant Protection Act and the Missouri Plant Law.

Study Questions

1. **What is the United States Plant Variety Protection Act?**
2. **What is a license agreement?**
3. **What is the Missouri Plant Law?**

Reference

1. Greenhouse Operation and Management (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

Lesson 24: Legal Considerations

TEACHING PROCEDURES

A. Introduction

B. Motivation

Show a copy of a license agreement. Ask if students know what it is and if they would be willing to sign such an agreement. Ask students to explain why they think it is necessary.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with students the plant variety act.

What is the United States Plant Variety Protection Act?

a) Goals of the U.S. Plant Variety Protection Act
   1) Encourage the development of new varieties and hybrids, and to make these hybrids available to the public
   2) Provide protection to the people who breed, develop, or discover the varieties and hybrids
b) Issues Plant Variety Protection certificates that provide legal protection to the holder for 18 years

NOTE: There are two exemptions that are allowed, one is for farmers and one for researchers. A farmer is allowed to save seed and either plant it the next year or sell it to other farmers. For a research exemption, work is allowed in the laboratory or in a breeding program to develop new lines.

2. Ask students what is the purpose of a business agreement. Compare a license agreement to the business agreement for the SAE program.

What is a license agreement?

It is an agreement in which the grower agrees to certain conditions in order to grow and sell the specified variety.

3. The Missouri Plant Law pertains mainly to nurseries, but since some greenhouse businesses handle nursery stock it has been included in this lesson.

What is the Missouri Plant Law?

a) The Missouri Plant Law is a booklet of the rules and regulations governing the production of nursery plants within Missouri.
b) The law requires nurseries to have their plants inspected at least once a year by the state entomologist. This official is chiefly looking for insects and diseases.

Other activities

1. Have students prepare a report on the United States Plant Protection Act or the Missouri Plant Law.

2. Have students write to the following address for information about the Missouri Plant Law.

Missouri Dept. of Agriculture
Office of the State Entomologist
P.O. Box 630
Jefferson City, MO 65102

G. Conclusion

Greenhouse growers must know about the different legal considerations they may encounter when growing plants. Certain legal agreements must be signed to protect companies that develop new plant varieties.

H. Competency

Describe the relevance of the United States Plant Protection Act and the Missouri Plant Law.

I. Answers to Evaluation

1. 1970
2. Encourage development of new varieties and hybrids and to make them available to the public. Also to provide protection to the people that breed, develop, or discover the new varieties or hybrids.

3. A fee payable to the breeder or plant company each time the variety is propagated or new seed is sown.

4. Any 2 of the following or others determined appropriate by the instructor: use the crop for a period of one year; pay the company a royalty for each cutting; report any mutations; agree to destroy the plants at the end of the agreement

5. State Entomologist
6. Insects and diseases

UNIT - GREENHOUSE OPERATION AND MANAGEMENT Name ____________________

Lesson 24: Legal Considerations Date ____________________

EVALUATION

Complete the following short answer questions.

1. When was the United States Plant Variety Protection Act passed?

2. What is the purpose of the United States Plant Variety Protection Act?

3. What is a royalty?

4. List two conditions a grower might agree to when signing a license agreement:

5. Who inspects nursery plants under the provision of the Missouri Plant Law?

6. What is the official in Question 5 looking for?

APPENDIX A

PRODUCTION SCHEDULE

POTTED PLANT CROPS

August: Sow cineraria and calceolaria seed. In late August, pot up rooted poinsettia cuttings.

September: Receive rooted mum cuttings. Pot up light pot mum cuttings for 2 weeks, pinch at the end of 2 weeks. Pinch poinsettias by 15th.

October: Apply growth regulators as needed to poinsettias prior to 15th.

November: Sell pot mums.
Poinsettias start showing color

December: Pot up Easter lilies.
Sell kalanchoes.
Sell poinsettias.
15th - Sow wax begonia seeds.
Start pansy seeds.

January: 15th - Transplant wax begonias. Sow seed geraniums and petunias. Take fuchsia cuttings and start hanging foliage baskets from cuttings.

February: Sow ageratums, snapdragons, cabbage, broccoli, and cauliflower.
Start tuberous begonias and gloxinias.
Start selling cinerarias and calceolarias.
Start taking geranium cuttings.

March: Sow coleus, impatiens, verbena, vinca rosea, dwarf marigold, flowering tobacco, balsam, portulaca, and sweet alyssum.

April: Start tomato seeds, celosia, pepper, eggplant, African marigold, cosmos, zinnia, and watermelon.
Order poinsettia cuttings.

May: Sell gloxinias and tuberous begonias.
15th - Wax begonias and other bedding plants are ready to sell.
Mother's Day weekend is good time to have a big plant sale.

June: Close up greenhouse for the summer. If stock foliage plants are left over, move them outside into a lathe house or shade.

APPENDIX B

CROP CULTURE SHEETS

- Chrysanthemum
- Foliage Plants
- Bedding Plants
- Easter Lily
- Tulip
- Geranium
- Calceolaria
- Cineraria
- Poinsettia

CROP CULTURE - CHRYSANTHEMUM

Scientific name:	Chrysanthemum morifolium
Common name:	Mum, pot mum, chrysanthemum, or florist's chrysanthemum
Description:	One of the most popular year-round flowering plants. Grown three ways: as a pot mum, as a cut flower, and as a garden mum. Comes in 9 different classes based on flower form
Sales period:	Year-round
Propagation:	Cuttings, usually obtained through a specialist propagator
Temperature:	1st 3 weeks 65°F (18°C) NT, 1st two weeks of short days, 62°-65°F (17°-18°C) NT, finish last two weeks at 50°-54°F (10°-12°C) NT to harden.
Growth regulators:	B-Nine® at 2,500 ppm when new growth after pinching is 2 to 2 1/2 inches long.
Fertility:	pH 6.0, most growers use CLF of 200-300 ppm N from 20-10-20 or 15-16-17. May also incorporate slow release fertilizer and use 200 ppm 20-10-20 CLF.
Pests:	Aphids, cyclamen mites, spider mites, leaf miners, mealybugs, thrips, whiteflies
Diseases:	Vertacillium wilt, septoria leaf spot, root rots, botrytis
Notes:	Plant cuttings in 5- to 6-inch pots. Most growers place 5 cuttings per 6-inch pot. They require a good porous medium. Since mums need short days (long nights), they require photoperiodic control. Short days occur naturally from September to March. Mums can be grown year-round by manipulating or artificially creating long nights. This is done by covering the plants every night at 6-7:00 p.m. with a black polyethylene plastic or black sateen cloth and uncovering them in the morning at 7-8:00 a.m. when the nights are not naturally short. To keep them vegetative, use artificial light at night - four hours of light during the night - 10 foot candles of light is sufficient - one 60W bulb every six feet with reflectors will do. The number of weeks they receive short days in order to bloom will depend on the variety. They are categorized, in catalogs, by week groups usually ranging from 7 weeks to 13 weeks. In any case, mums are given 1-2 weeks of long days in summer and 2-3 weeks in winter to develop sufficient vegetative growth before being allowed to flower (short day treatment). Refer to cutting supplier for complete information on scheduling each cultivar since production schedules may vary. There are three primary ways to grow mums: 1. spray - no buds are removed 2. dispray - has had the large middle or terminal bud removed 3. disbud - only the side or lateral buds are removed Spacing: 5-inch pots - allow 1" between pots for first 3-4 weeks, then 5"

CROP CULTURE - FOLIAGE PLANTS

Common name:	Green plants, houseplants
Description:	Plants capable of adapting to indoor conditions fall into this category. They come from a wide variety of origins with varying cultural requirements.
Sales period:	Year-round, but sales are higher in winter months.
Propagation:	Varied, usually asexual (stem tip cutting), few grown from seed (asparagus fern), now tissue culture being used more
Temperature:	65-70°F (18°-21°C) for most
Growth regulators:	NA
Fertility:	20-10-20, 150 ppm CLF - slow-release fertilizer often used
Pests:	Mealybugs, spider mites, and scale are most common.
Diseases:	Varies according to plant, most susceptible to stem and root rots
Notes:	Most grow best in artificial mix that is high in organic matter.
	Most commonly used in homes, also malls, businesses for interior landscaping

CROP CULTURE - BEDDING PLANTS

Common name: Bedding plants

Description: Defined as plants grown to be planted outside in beds. Impatiens, petunia and marigold are the three most popular bedding plants.

Sales period: Spring

Propagation: Depends on plant, most are by seed, but some by cutting

Temperature: Ranges from 55°F (13°C) to 65°F (18°C), depending on species; needs to be warmer after transplanting, gradually lower the last two weeks before selling

Growth regulators: Used on some plants (e.g,. B-Nine® on petunias, Cycocel® on seed geraniums)

Fertility: 100-250 ppm CLF depending on species

Pests: Aphids, mites, fungus gnats, whiteflies

Diseases: Root rots, botrytis, damping-off

Notes: Production schedule:
January: seed geraniums and petunias, take fuchsia cuttings for hanging baskets

February: seed ageratum, snapdragon, cabbage, broccoli, cauliflower

March: seed coleus, impatiens, verbena, vinca rosea, dwarf marigold, flowering tobacco, balsam, portulaca, and sweet alyssum; take geraniums cuttings

Middle of March and early April: seed celosia, tomato, pepper, eggplant, African marigold, cosmos, zinnia, and watermelon

Plugs can be purchased which may be cheaper in the long run.

CROP CULTURE - EASTER LILY

Scientific name: Lilium longiflorum

Common name: Easter lily

Description: Grown almost exclusively as a potted plant for sale at Easter.

Sales period: Starting Palm Sunday

Propagation: Bulbs - from scales

Temperature: If purchasing precooled bulbs, grow at 63°F (17°C) NT. Rate of growth can be controlled by lowering or raising temperature (e.g., to increase height; light at night).

Fertility: pH of 6.5-7.0; high N level 400 ppm. Start when root system is well established(i.e., top growth 1-2" high)

Pests: Aphids, bulb mites, fungus gnats

Diseases: Root rots, botrytis, leaf scorch, tip burn

Notes: Bulbs are received about Dec. 10.

Timing is difficult as Easter varies from year to year within a 4 1/2 week span.

Bulbs held in cold storage for late planting will take less time to flower. They need 115-120 days from time of potting to flowering.

Ace and Nellie White are the two most popular varieties. It is best to purchase 8-9 cm size bulbs. These will have 5 and 6 flowers per bulb. If no refrigerator space is available, it's best to buy precooled bulbs.

Pot immediately upon arrival in 5 1/2-inch or 6-inch standard pots, about 2" deep. Chill at 40°-45°F (4°-7°C) for 5-6 weeks depending upon cultivar.

At the first sign of root rot (plant suddenly stops growing, top wilts easily, lower leaves turn yellow), drench entire crop with fungicide.

CROP CULTURE - TULIP

Scientific name:	*Tulipa sp.*
Common name:	Tulip
Description:	Tulips are generally grown as potted plants, however some are sold as cut flowers. They are sold in a variety of colors excluding blue.
Sales period:	Spring, some varieties are forced early for Valentine's Day.
Propagation:	Bulb
Temperature:	Rooting room temperature 48°F (9°C), greenhouse forcing temperature 63°F (17°C) NT, 68°F (20°C) DT
Growth regulators:	NA
Fertility:	Calcium nitrate at 2 lbs/100 gal weekly
Pests:	Aphids, mites, fungus gnats
Diseases:	Root rots, botrytis
Notes:	Bulbs potted in late September - mid November depending on cultivar and flower date desired. Pot with the flat side of the bulb out toward the pot wall, usually six bulbs in a 6-inch pot. Water thoroughly. Media should be well-drained. Be sure to water bulbs while they are in the rooting room. Can purchase precooled bulbs. Need cool moist conditions. When buds show first sign of color, they are ready to be sold. Bulbs potted the 4th week of October, cooled until February 18th, forced at 69°F (20°C) will be in bloom March 11.

CROP CULTURE - GERANIUM

Scientific name: Pelargonium x hortorum

Common name: Geranium

Description: Popular outdoor bedding plant. Colors: red, white, pink, orange, purple.

Sales Period: Spring bedding sales, especially Mother's Day and Memorial Day

Propagation: Cuttings taken starting mid-February. Root for approximately 2 weeks in sand or oasis strips with bottom heat. Do not over mist. Temperature: 65°-70°F (18°-21°C) NT.

Growth Retardant: Apply Cycocel® 1500 ppm about 3-4 weeks after transplanting. This will speed up flowering and help promote basal branching as well as shorter plants. Do not water for 24 hours after spraying.

Fertility: 15-16-17, 250 ppm CLF; high P; watch for Magnesium and Boron deficiency

Pests: Aphids, whiteflies, spider mites

Diseases: Botrytis, bacterial leaf spot

Notes: Approximately 18 weeks from cutting to a blooming size in 4-inch pot

Best to purchase culture virus indexed cuttings

Can root own cuttings or purchased calloused cuttings or rooted cuttings

Odema is a physiological, noninfectious disorder in which corky blisters appear on lower leaf surfaces. Make sure geraniums are spaced out, have good ventilation, and are watered uniformly.

CROP CULTURE - CALCEOLARIA

Scientific name:	Calceolaria herbeohybrida
Common name:	Pocketbook plant, Calceolaria
Description:	This colorful potted plant is a true annual. Pouch-shaped blooms are the cause for its name of pocketbook plant. They come in red, yellow, and orange.
Sales period:	Spring, usually Easter. On the west coast, it is grown as a bedding plant.
Propagation:	Sow in July and August
Temperature:	60°-70°F (15°-21°C) for seed germination; 45°-50°F (7°-10°C) NT for 6 weeks in order to bloom; temperature raised to 60°F (15°C) when flower buds are visible
Growth regulators:	NA
Fertility:	200 ppm CLF of 20-10-20 or 15-16-17
Pests:	Aphids, leaf rollers, mealybugs, thrips, whiteflies
Diseases:	Virus that is carried by aphids, stem rot
Notes:	Will not bloom all at once. Lighting at night will speed forcing but tends to stretch plant which causes poorer quality and fewer flowers. Too much light burns the foliage. Light shade is recommended. Overwatering will cause leaves to yellow.

CROP CULTURE - CINERARIA

Scientific name:	Senecio x hybridus
Common name:	Florist's cineraria or cineraria
Description:	Colorful, inexpensive potted plant. A true annual, the daisy-like flowers come in colors of red, purple, pink, and blue; some have a white "eye".
Sales period:	January through May
Propagation	Seed - sow in August and September for mid-winter to Easter sales for 5" to 6" plants.
Temperature:	48°-50°F (9°-10°C) NT after seedlings are established. Need temperatures below 60°F (15°C) for six weeks in order to bloom
Growth regulators:	Apply B-Nine® at 2500 ppm as soon as established.
Fertility:	Apply 250 ppm of 20-10-20 or 15-16-17 at CLF.
Pests:	Aphids, mealybugs, spider mites, thrips, whiteflies
Diseases:	Verticillium wilt, mosaic, stem rot, powdery mildew
Notes:	Cineraria plants need to be transplanted as soon as they can be handled - very susceptible to damping-off. Protect from strong sun when in bloom. Sterilize all pots, flats etc. Drench with fungicide regularly. They need lots of water when in bloom.

CROP CULTURE - POINSETTIA

Scientific name:	Euphorbia pulcherrima
Common name:	Poinsettia
Description:	Poinsettias are short-day plants. They need no more than 12 1/2 hours of daylight at 62°-70°F (16°-21°C) in order to bloom. Natural induction occurs in late September - early October. "Stray Light" after September 25 can prevent blooming.
Sales period:	Starting Thanksgiving - normal flowering for most varieties
Propagation:	Stem tip cuttings 2" to 3" long; start propagation in July and August. Root in about 3 weeks; mist from sunrise to sunset for 12 sec/5 minutes. Oasis cubes, (be sure to leach first), jiffy 7's, or direct stick (root in small containers) can be used to start cuttings. Rooted cuttings should be potted in late August.
Pinch:	About two weeks after potting up, check roots. If good root development, pinch plants leaving 5-6 leaves. Pinching must be done prior to September 15.
Temperature:	65°-68°F (18°-20°C) NT, lower temperature to 60°-65°F (15°-18°C) last 2 weeks
Fertility:	pH of 5.5-6.0; NO3 level 300 ppm - greater than average requirement for N, K, Mg., MN, Mo; 20-10-20 CLF or use poinsettia fertilizer 15-5-25. A well-drained peat-lite mix is essential for good root growth.
Growth regulator:	Apply Cycocel® at 1500 ppm when new leaves after pinching are 1-2 inches long - repeat as needed. Do not apply growth retardant after October 15th.
Spacing:	For 6-inch plant: 1 pinched cutting/pot 12 x 14
Pests:	Whiteflies, fungus gnats
Diseases:	Root rots, botrytis
Notes:	Drench monthly with Ban Rot® or Truban/Benlate®. Check regularly for pests. Poinsettias like a well-drained growing medium. Do not overwater.
	For small grower, it is recommended to buy rooted cuttings or 2 1/4-inch plants from a specialist.

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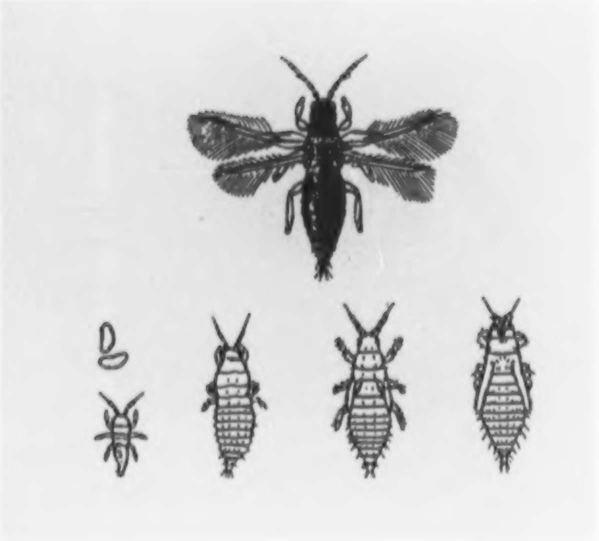
10-2010-S

Greenhouse Operation and Management

Student Reference



In cooperation with
Agricultural Education
Department of Practical Arts and
Vocational-Technical Education
College of Education and
College of Agriculture
University of Missouri-Columbia

In cooperation with
Agricultural Education Section
Division of Vocational and
Adult Education
Department of Elementary and
Secondary Education
Jefferson City, Missouri

In this guide, trade names are used as examples. No endorsement is intended for products mentioned.

The activity which is the subject of this report was supported in whole or in part by funds from the Department of Elementary and Secondary Education, Division of Vocational and Adult Education. However, the opinions expressed herein do not necessarily reflect the position or policies of the Missouri Department of Elementary and Secondary Education or the Division of Vocational and Adult Education, and no official endorsement should be inferred.

Student Reference

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Volume 21
Number 4

Catalog Number 10-2010-S
January, 1990

ACKNOWLEDGEMENTS

Recognition is given to advisory committee members for providing their valuable time and suggestions in developing this unit. The committee consisted of Ralph Ball, Jim Bellis, Steven King, Delbert Lund, Robert Mareth, Bob McConnell, Richard McConnell, Barbara Rothenberger, Ramona Schescke, and David Trinklein.

Special recognition is given to Barbara Rothenberger for writing a portion of the material. Some illustrations were prepared by Dodge Art Works, Columbia.

Appreciation is expressed to the following staff members of the Instructional Materials Laboratory for their efforts in producing this material: Harley Schlichting, Director; Amon Herd, Associate Director; Phyllis Miller, Assistant Director; Dan Stapleton, Assistant Director; Crystal Dietiker, Graphic Artist II; Christen Heitkamp and Lori Holliday, Word Processors; Barbara Tidquist, Graduate Technical Assistant; and Karen Omer and Janece Seward, Editorial Assistants.

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FOREWORD

The development of the Greenhouse Operation and Management guide is the result of suggestions by the MVATA Teaching Aids Committee. The Greenhouse Operation and Management Advisory Committee suggested the topics to be discussed and reviewed the materials.

This student reference contains 24 lessons, which cover a wide range of topics including: greenhouse structures, greenhouse environmental control, plant processes, growth regulation, growing media, pests, pesticide safety, and record keeping. See the table of contents for a detailed listing. A glossary is included at the end of this guide. Those using this publication on an individual basis may want to obtain a copy of the instructor guide, which contains additional information.

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GREENHOUSE OPERATION AND MANAGEMENT

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In order to understand the greenhouse (floriculture) industry, it is important to be familiar with its past, present, and future. This unit will examine the four divisions of horticulture and where greenhouse operation and management fits. The history and development of the greenhouse industry, major production areas, and the importance of greenhouse operations in Missouri, the United States, and the world will be explored.

Horticulture

The term horticulture is derived from the Latin hortus meaning "garden" and cultura meaning "cultivation" or "care of." Today when the term horticulture is used, it means much more than garden cultivation. Horticulture is the cultivation, processing, and sale of fruits, nuts, vegetables, ornamental plants, and flowers. Since horticulture deals with such a vast array of plants, it has been divided into four major divisions.

Pomology - This term is derived from the Latin pomum meaning "fruit" and logy meaning "the study of." Pomology is the science and practice of growing, harvesting, handling, storing, processing, and marketing of tree fruits. Tree fruits include apples, pears, stone fruits, citrus fruits, nuts, grapes, various berry crops, and assorted temperate, subtropical, and tropical fruits.

Olericulture - This term is derived from the Latin oleri meaning "vegetables" and cultura meaning "cultivation" or "care of." Olericulture is the science and practice of growing, harvesting, storing, processing, and marketing of vegetables.

Ornamental horticulture - The science and practice of propagating, growing, maintaining, and using a plant that is grown for its beauty is called ornamental horticulture. Grasses, annual plants, shrubs, and trees are all considered ornamental.

Floriculture - The term flora derives from the Roman mythological name for the goddess of flowers, and cultura, again, means "cultivation" or "care of." Floriculture is the science and practice of growing, harvesting, storing, designing, and marketing plants. Cut flowers, flowering container-grown plants, foliage plants, bedding plants, and cut cultivated greens are all included in floriculture. The majority of flowering plants are produced in greenhouses.

Evolvement of the Greenhouse Industry

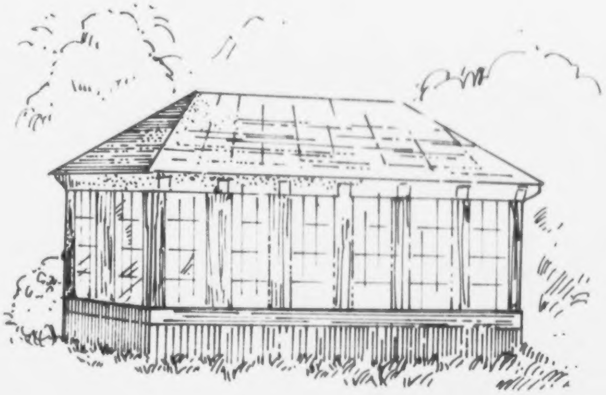
Greenhouses in one form or another have been around since the first century A.D. Roman emperors used "specularia" to protect tender plants. These were pits covered with thin slabs of talc or sheets of mica. Emperor Nero reportedly ate cucumbers grown year-round in specularia.

During the Dark Ages a Dominican monk, Albertus Magnus (1193-1280 A.D.), was charged with witchcraft for forcing flowers to bloom out of their natural season. In the 17th century, the European royalty fancied spring flowers in the winter and fruit out of season. "Orangeries" were very popular at that time for the protection and forcing of citrus trees. At Heidelberg, Germany, in 1619 one orangery contained 40 mature and 300 small citrus trees.

"Conservatories" became popular in Victorian England. They contained exotic tropical flowering and foliage plants brought home by English explorers. Many of these conservatories had glass sidewalls and an opaque roof.

The first documented greenhouse built in the United States was constructed around 1710 in Boston. It was built by Andrew Faneuil on the estate of Governor Bellingham. This first greenhouse may have looked similar to the 1764 American greenhouse pictured in Figure 1.1. George Washington had a greenhouse in 1789 which consisted of solid walls and skylights. At Monticello, Thomas Jefferson built a greenhouse similar to the English conservatories.

Figure 1.1 - 1764 American Greenhouse



Credit: Geo. J. Ball, Inc., "Grower Talks"

Up until this point greenhouses had been enjoyed and used only by the rich. In 1780 less than 100 florists were in the United States. Their combined glass structures covered only 50,000 square feet. The floriculture crops produced were perishable and the type of transportation used then made it necessary for production to be close to the markets. The greenhouse industry began to flourish during the nineteenth century in the U.S. because of technology brought by European immigrants. The floriculture industry first developed around population centers like Boston, New York, Philadelphia, and later Chicago.

Commercial greenhouses became an important part of the United States economy after the industrial development that followed the Civil War. Almost 5,000 commercial greenhouse ranges existed by 1880. They covered a total of 38,823,247 square feet. They provided cut flowers and vegetables for local markets.

Around the 1950s, the use of refrigerated trucks and railroad cars as well as jet transportation enabled floriculture growers to market their products over a much larger distance than before. This made it possible to produce cut flowers in areas where warmer climates enabled lower production costs. Container-grown plants are still being grown in areas close to the market because of the low cost and ease of transportation.

Intercontinental jet transportation has also made it possible to produce cut flowers where environmental factors are ideal and labor costs are low. Carnations were first grown in Bogota, Colombia, in South America in 1966. Now there are over 50 Bogota firms, covering more than 500 acres, which produce only cut carnations. This trend of South American production continued with cut chrysanthemums and cut roses.

Within the last seven years there has been a moderate flow of floral products from the Netherlands. In the Netherlands growers specialize in a single crop or related crops. Their crop production is highly automated. The growers then market their crops using the auction market system.

Greenhouse Operations in Missouri

Greenhouse operations are important in Missouri for the production of cut flowers, container-grown flowering plants, foliage plants, and bedding plants. According to the "Floriculture Crops 1986 Summary," there were 121 Missouri growers in 1986, each earning an annual gross income of $10,000 or more. Missouri had a total of 4,906,000 square feet of greenhouse area in production during 1986. The wholesale value of the floriculture crops produced in Missouri in 1986 totaled $26,177,000.

Greenhouse Operations in the United States

The "Floriculture Crops 1986 Summary" surveyed greenhouse growers across the nation. The 1986 wholesale value of floriculture crops for the 28 crops surveyed in the 28 states totaled $1.88 billion. See Table 1.1 for an explanation of these crop categories with their wholesale values.

Table 1.1 - Summary of the 1986 Value of Sales at the Wholesale Level

Crop Category	Wholesale Value in Million Dollars
Bedding Plants	547.1
Foliage Plants	515.5
Container-grown Flowering Plants	386.4
Cut Flowers	359.2
Cut Cultivated Greens	70.4
Total Value of Reported Crops	1,878.6

Credit: Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987.

According to the same report, there were 6,907 growers in the United States, each earning a minimum annual gross income of $10,000 in 1986. A total of 341 million square feet of greenhouse space was in floriculture production.

Greenhouse Operations in the World

Like Missouri and the U.S. greenhouses, world-wide greenhouse operations are important for the vast array of products grown, employment opportunities, and income-producing capabilities.

Plants are important because they satisfy psychological needs. One major reason a customer purchases a floriculture product is to satisfy or fulfill an emotional need in human beings. Whether the flower or foliage plant is bought as a gift, as a remembrance, or as a decoration, there will always be emotional value attached to the purchase. In addition, floriculture products are very effective for use in horticultural therapy (the use of plant or plant-related activities to benefit people), especially people with handicapping conditions.

European countries are more advanced in incorporating floriculture products into daily life. In Europe, fresh flowers and plants are commonly purchased weekly, if not more often. There has been a marked increase in the amount of floriculture crops imported to the United States from South America, Australia, New Zealand, and Israel. These are areas where the climate is favorable and both labor and land costs are low. Although these factors are far from ideal in the Netherlands, advanced automation and specialization enable this country to export floriculture products to the U.S.

Major Greenhouse Production States in the United States

There has been a change in the major floriculture production areas in the United States. Twenty years ago the major regions of floriculture production were the Midwest and East. However,the "Sunbelt States" of California, Texas, and Florida enjoy a warm climate, allowing for much year-around outdoor floriculture, thus saving on greenhouse overhead and energy costs. Southern greenhouses are less expensive to construct because they do not have to be as sturdily built in order to withstand heavy snow loads. In general, labor is more readily available at a lower salary in these states. The remainder of the leading states in floriculture production are all located in densely populated states, offering much available labor. Such urbanized states have a high demand for floriculture products, with a huge potential market area nearby for ease of shipping. Similarly, the central location of Ohio and Pennsylvania results in lower shipping costs of floriculture products. See Table 1.2

Leading States in Production of Each Floriculture Crop Category

Only the states of Florida and California appeared on the list of the five top-producing states in every crop category. See Tables 1.3 to 1.7. Many of the top-producing states, however, were listed in multiple categories. Hawaii is notable because it ranks fourth in cut flower production, fifth in foliage plant production, and third in cut cultivated greens production, even though Hawaii is not one of the top seven floriculture-producing states.

Table 1.2 - 1986 Overall Floriculture Production

Rank	State	Wholesale Value in Million Dollars
1	Florida	484
2	California	430
3	Ohio	100
4	Pennsylvania	94
5	Michigan	84
6	New York	82
7	Texas	72
17	Missouri	26
Total Floriculture Crops Produced in the Top Seven States:		1,346

Credit: Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987.

Florida leads in the overall production of floriculture products. Florida produces over 94 percent of the cut cultivated greens and 60 percent of all foliage plants produced in the United States. It ranks second in the production of cut flowers.

California is the second leading state in the overall production of floriculture products. It is the leading state in the production of cut flowers, producing over 53 percent of the total cut flowers grown in the United States. It is the leading state in producing flowering container-grown plants (21 percent), and the second leading state in the production of foliage plants. California is the leading state in the production of bedding plants, growing 11 percent of the total United States production.

Ohio is the third leading state in the overall production of floriculture crops. It is ranked fifth by producing 6 percent of the flowering container-grown plants grown in the United States. It is ranked fourth in the production of foliage plants and second in bedding plant production.

Pennsylvania is the fourth leading state in the overall production of floriculture crops and in the production of flowering container-grown plants by growing 6 percent. It is ranked fifth in both cut flower and bedding plant production. Michigan is the fifth leading state in the overall production of floriculture crops, ranking third in total bedding plants grown. New York is the sixth leading state

Table 1.3 - Leading Cut Flower Production States in 1986

Rank	State	Wholesale Value in Million Dollars	Percentage of Total Production
1	California	190	53
2	Florida	26	7
3	Colorado	23	6
4	Hawaii	17	5
5	Pennsylvania	16	5
6	Other	87	24
Total Cut Flowers Produced:		359	100

Credit: Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987.

Table 1.4 - Container-grown Flowering Plant Production in 1986

Rank	State	Wholesale Value in Million Dollars	Percentage of Total Production
1	California	81	21
2	Florida	36	9
3	New York	30	8
4	Pennsylvania	24	6
5	Ohio	23	6
6	Other	192	50
Total Container-grown Flowering Plants:		386	100

Credit: Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987.

in overall production, ranking third in the production of container-grown flowering plants and seventh in both cut flower and foliage plants grown. Texas is the seventh state in overall floriculture crop production. Texas ranks third in foliage plants, fourth in cut cultivated greens, and sixth in container-grown flowering plants grown.

Summary

Horticulture is divided into four sectors: pomology, olericulture, ornamental horticulture, and floriculture. Most floriculture crops, including cut flowers, container-grown flowering plants, foliage plants, bedding plants, and cut cultivated greens, are greenhouse-grown. The greenhouse industry is a major economic force, with a wholesale value of $26 million in Missouri and $1.88 billion in the United States during 1986. Benefits of the floriculture industry are a vast array of products, employment opportunities, income potential, and an effective means for horticultural therapy activities.

Table 1.5 - Foliage Plant Production in 1986

Rank	State	Wholesale Value in Million Dollars	Percentage of Total Production
1	Florida	309	60
2	California	95	19
3	Texas	21	4
4	Ohio	14	3
5	Hawaii	13	3
6	Other	631	1
Total Foliage Plants Produced:		515	100

Credit: Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987.

Table 1.6 - Bedding Plant Production in 1986

Rank	State	Wholesale Value in Million Dollars	Percentage of Total Production
1	California	62	11
2	Ohio	54	10
3	Michigan	54	10
4	Florida	46	8
5	Pennsylvania	43	8
6	Other	288	53
Total Bedding Plants Produced:		547	100

Credit: Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987.

Table 1.7 - Cut Cultivated Greens Production in 1986

Rank	State	Wholesale Value in Million Dollars	Percentage of Total Production
1	Florida	66.7	94
2	California	2.4	3
3	Hawaii	.7	less than 1
4	Texas	.4	less than 1
5	Indiana	.1	less than 1
6	Other	Not significant	less than 1
Total Cut Cultivated Greens Produced:		70.3	100

Credit: Agricultural Statistics Board. Floriculture Crops 1986 Summary. Washington, D.C.: United States Department of Agriculture, 1987.

Credits

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Currently, the greenhouse industries in both Missouri and the United States are expanding economically. The wholesale value of Missouri floriculture crops grown in 1986 and a cost analysis of an average sized Missouri greenhouse business as of 1987 will be presented.

The Value of Greenhouse Crops Grown in Missouri

Missouri ranked 17th nationally in floriculture crop production in 1986, growing floriculture crops worth a total wholesale value of $26 million. Currently, opportunities in the Missouri greenhouse industry are expanding. Table 2.1, found at the end of this lesson, gives the overall production picture of the floriculture industry in Missouri. This table also includes a financial analysis for each major crop.

Percentage of Floriculture Crops Grown in Missouri

Missouri produced 26 million dollars worth of floriculture crops in 1986. The total value of floriculture products grown in the United States in 1986 was 1.88 billion dollars. Missouri produced almost 1.4 percent of the floriculture crops produced in the United States for that year. Seventy-one percent or 20 of the 28 crops reported to the U.S.D.A. are produced in Missouri. In Table 2.2 the floriculture crops grown in Missouri are listed in order of economic importance.

Table 2.2 - Economic Importance of Floriculture Crops Produced in Missouri

Rank	Floriculture Crop	Wholesale Value in Thousands
Cut Flowers		
1	Mums, glads and roses	1,001
2	Carnations, standard	15
	Other cut flowers	30
	Total Cut Flowers Produced in Missouri	$1,046
Container-Grown Flowering Plants		
1	Poinsettias	2,880
2	Mums	1,527
3	Easter lilies	755
4	Azaleas	257
5	African violets	153
6	Other lilies	133
	Other flowering plants	2,613
	Total Container-Grown Flowering Plants	$8,318
Foliage Plants		
1	Potted foliage	1,871
2	Hanging baskets	656
	Total Foliage Plants	$2,527
Bedding/Garden Plants		
1	Bedding plants (flats excluding those listed below)	7,411
2	Vegetable type bedding plants (flats)	2,167
3	Flowering hanging baskets	1,260
4	Potted geraniums (cuttings)	1,062
5	Potted geraniums (seed)	700
6	Potted hardy/garden mums	662
7	Bedding geraniums (flats)	582
8.	Potted vegetable type bedding plants	29
	Other potted flowering and foliar type bedding plants	368
	Total Bedding Plants	$14,241
	Total Wholesale Value of Floriculture Crops Produced in Missouri During 1986	$26,177

Cost Analysis of Operating the Average Missouri Greenhouse

Very few studies have been made in the United States to develop an all-inclusive set of greenhouse operating expenses, due to the many variables involved. Some of these variables are the size, the marketing outlet (mass market or flower shop), location, automation, the type of covering material, and rapidly changing economic conditions.

Importantly, the rapid rise in energy costs during recent years has caused much interest in energy conservation measures. In fact, in northern states, fuel cost represents the second greatest greenhouse operating expense. Fuel expense is expected to continue increasing as the world's supply of fossil fuel continues to diminish.

Greenhouse operating expenses may be divided into two categories. The first is fixed or overhead expenses. These are ongoing ownership costs of running a greenhouse business, regardless of whether or not crops are being grown. Sometimes these are called indirect costs. Some examples of overhead expenses are purchase price of the greenhouse business and all equipment, maintenance, interest, taxes, depreciation, and insurance. For instance, the upkeep and repair to the facility and equipment is a continuous process and must be included in the annual budget of the floriculture firm. Another example involves figuring depreciation. Depreciation is a way of allocating the assets of the greenhouse business over time. If a glass greenhouse is expected to have a useful life span of 20 years, depreciation would be calculated by dividing its purchase price by 20, resulting in an annual depreciation cost.

The second category of greenhouse operating expenses includes the direct or variable costs which relate directly to the crop being grown. This category may also be referred to as the cost of production per crop. Some examples of variable expenses are labor, fuel, marketing, growing, and cultural supplies. Production costs have increased due to stricter government regulations concerning labor safety, environmental pollution, pesticide use, energy allocation, and interstate commerce. Direct expenses will increase proportionately as the number of plants being grown increases.

The following information is an estimation of the costs incurred by an average sized Missouri greenhouse business during 1987.

Table 2.3 - Estimated Cost Analysis of an Average Sized Missouri Greenhouse Business During 1987

Expense	Percentage of Total Expense
Labor	33
Fuel	25
Marketing/selling	15
Cultural supplies	12
Depreciation	5
Maintenance/repair	4
Other items	6
	100

The other items which complete the final six percent might include one or more of the following: property tax, interest expense, truck operation, electricity, office expense, insurance, water, telephone, dues and subscriptions, land rental and bad debts.

Summary

Missouri-produced floriculture crops in 1986 were worth a total wholesale value of $26 million. Thus, Missouri ranked 17th nationally, growing nearly 1.4 percent of all United States floriculture crops. Labor and heating costs are the two top greenhouse operating expenses, followed by marketing, cultural supplies, depreciation, and maintenance.

Credits

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Table 2.1 [illegible]riculture Crops Produced in Missouri in 1986

Crop Produced	Number of Commercial Growers	Production Area in Square Feet	Number of Pots Sold	Containers Less Than 5 Inches	Containers Greater Than 5 Inches	% of Sales Sold at Wholesale Price	Wholesale Price Per Plant	Value of Sales at Wholesale	Intended Production in 1987 (# of containers, hanging baskets, flats)	1987 Production as % of 1986 Production
CONTAINER-GROWN FLOWERING PLANTS										
African violets	12	20,000	102,000	96,000	6,000	94%	$1.50	$153,000	102,000	100%
Container grown mums	27	323,000	423,000	55,000	368,000	98%	$3.61	$1,527,000	445,000	105%
Azaleas	24	31,000	36,000	none	36,000	86%	$7.13	$257,000	33,000	92%
Easter lilies	29	112,000	186,000	1,000	185,000	97%	$4.06	$755,000	188,000	101%
Other container-grown lilies	18	17,000	37,000	none	37,000	91%	$3.59	$133,000	37,000	100%
Poinsettas	72	1,072,000	699,000	78,000	621,000	89%	$4.12	$2,880,000	746,000	107%
Other container-grown flowering plants	41	458,000	950,000	523,000	427,000	80%	$2.75	$2,613,000	877,000	92%
FOLIAGE PLANTS										
Container-grown foliage	44	250,000	data not available	data not available	data not available	89%	data not available	$1,871,000	251,000	100%
Foliage hanging baskets	40	data not available	135,000	data not available	data not available	92%	$4.86	$656,000	139,000	103%
BEDDING PLANTS (flats)										
Geraniums	39	101,000	62,000	data not available	data not available	68%	$9.39	$582,000	54,000	87%
Other flowering or foliar bedding plants	92	1,610,000	1,071,000	data not available	data not available	82%	$6.92	$7,411,000	1,186,000	111%
Vegetable bedding plants	89	582,000	338,000	data not available	data not available	76%	$6.41	$2,162,000	354,000	105%
CONTAINER-GROWN BEDDING PLANTS										
Hardy/garden mums	67	300,000	341,000	107,000	234,000	72%	$1.94	$662,000	349,000	102%
Geraniums (grown from cuttings)	88	358,000	908,000	834,000	74,000	65%	$1.17	$1,062,000	947,000	104%
Geraniums (grown from seed)	45	205,000	722,000	707,000	15,000	85%	$.97	$700,000	628,000	87%
Other flowering and foliar bedding plants	53	180,000	418,000	381,000	37,000	68%	$.88	$368,000	442,000	106%
Vegetable bedding plants	33	20,000	61,000	53,000	8,000	63%	$.48	$29,000	64,000	105%
Flowering hanging baskets	63	data not available	215,000	data not available	data not available	85%	$5.86	$1,260,000	233,000	108%
CUT FLOWERS										
Carnations, standard	5	4,000	plants 10,000 blooms 75,000	data not available	data not available	3%	$.20/bloom	$15,000	3,000	75%
Missouri produces cut chrysanthemums (both pompons and standards), cut gladioli, and cut roses (both hydrid tea and sweetheart), but the figures for these crops are not included to avoid disclosure of individual operations.										
Cut flowers (other than those listed above)	11	12,000	data not available	data not available	data not available	100%	data not available	$30,000	11,000	92%
Total cut flowers								$1,046,000		

Information compiled from "Floriculture Crops of 1986 Summary," United Stated Department of Agriculture, National Agriculture Statistics Service, Agricultural Statistics Board.

There are many career opportunities in the greenhouse industry; the achievement of goals depends on wise planning. In order to plan for a future in this industry, a greenhouse worker needs to be aware of the following: the differences between grower, wholesaler, and retailer; the management structure within the greenhouse; and career opportunities in the greenhouse industry.

Differences Between Grower, Wholesaler, and Retailer

All types of businesses have three levels: producers, wholesalers, and retailers. The same is true for the greenhouse industry; however, instead of producers, the term grower is used.

Grower - The grower produces one or more crops for sale at the wholesale level. The grower generally specializes in just one crop, such as roses or tropical green plants. The grower becomes an expert on production and usually leaves marketing to the wholesalers. Some growers market their products, making sales an important part of their business.

Wholesaler - The wholesaler sells products to retail businesses. The wholesaler may sell flowers and plants from a grower on consignment. If this is the case, the wholesaler will deduct a commission from the selling price and remit the balance to the grower. The grower may then send the product directly to the retailer.

The wholesaler generally carries or has access to a wide range of floriculture crops and products. These products may include vases, floral tape, silk flowers, ribbon, and wire. The wholesaler provides a supermarket of horticulture products and supplies for sale to the retailers.

Retailer - The retailer sells products to the general public. Retailers are located in preferred retail marketing areas, making it easy for the customer to come to them. Retailers of floriculture products can be florist shops, retail greenhouses, or general retail stores.

A retail greenhouse will produce a portion of their own merchandise. Usually the retail greenhouse produces small quantities of a large selection of flowers or plants continuously. The retail greenhouse is the most common greenhouse operation in the state of Missouri. However, most operations combine aspects of all three areas into their businesses.

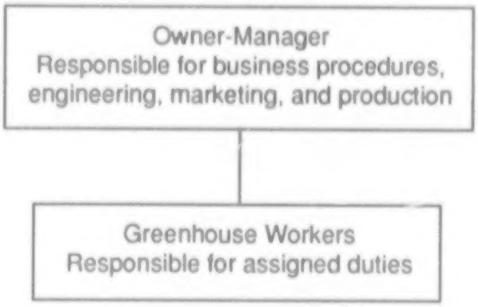
Management Structure of the Greenhouse

Greenhouses are generally small businesses, employing from one to 100 individuals. Many greenhouse businesses start as a side venture for a family and increase in size as the family grows. Management objectives are similar, regardless of the size of the greenhouse operation. Workers supply labor to carry out the plans developed by management. Management directs labor, time, and materials.

There are four areas of greenhouse operations: business procedures, engineering, production, and marketing. Business procedures involve record keeping for tax and cost accounting, billing, purchasing, and payroll administration. The engineering area maintains the physical plant, equipment, and vehicles. Usually the engineering area is responsible for custom-building (i.e., racks, buildings, and benches). The production area is directly involved with producing the crops. The last area is marketing. Marketing solicits orders, packages the crop, delivers, and performs other services at the point of sale.

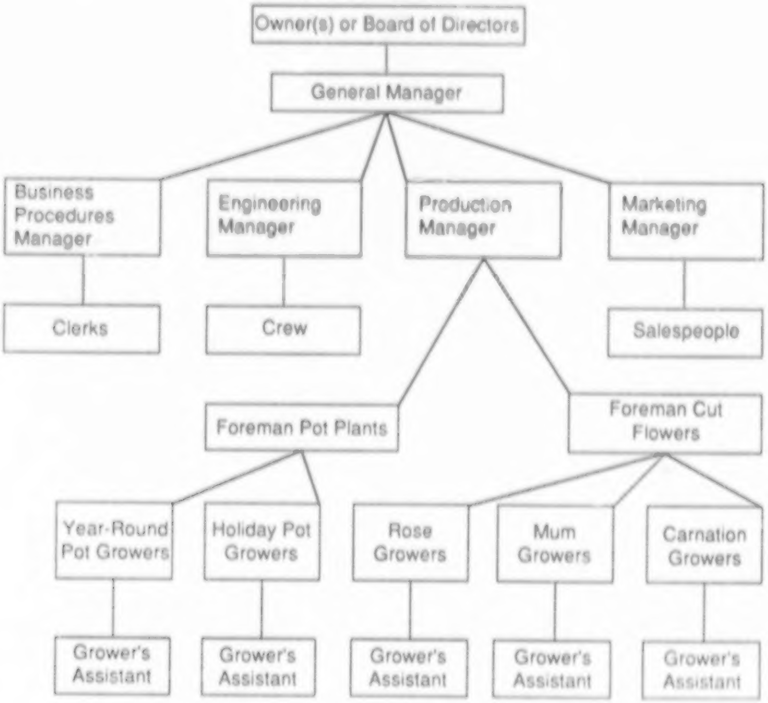
In a small operation, there may be only one manager, usually the owner. This manager is responsible for all four areas of the greenhouse operation, although he may have workers who perform assigned duties. See Figure 3.1.

Figure 3.1 - Single Owner/Manager


Owner-Manager
Responsible for business procedures, engineering, marketing, and production
Greenhouse Workers
Responsible for assigned duties

As the business grows, it is no longer practical for the owner to manage the entire operation. Other people are hired to share the management responsibilities, and the owner often becomes a general manager. The new manager of each area will be in charge of workers in their department. See Figure 3.2.

Figure 3.2 - Large Greenhouse Business


Owner(s) or Board of Directors
General Manager
Business Procedures Manager
Engineering Manager
Production Manager
Marketing Manager
Clerks
Crew
Salespeople
Foreman Pot Plants
Foreman Cut Flowers
Year-Round Pot Growers
Holiday Pot Growers
Rose Growers
Mum Growers
Carnation Growers
Grower's Assistant
Grower's Assistant
Grower's Assistant
Grower's Assistant
Grower's Assistant

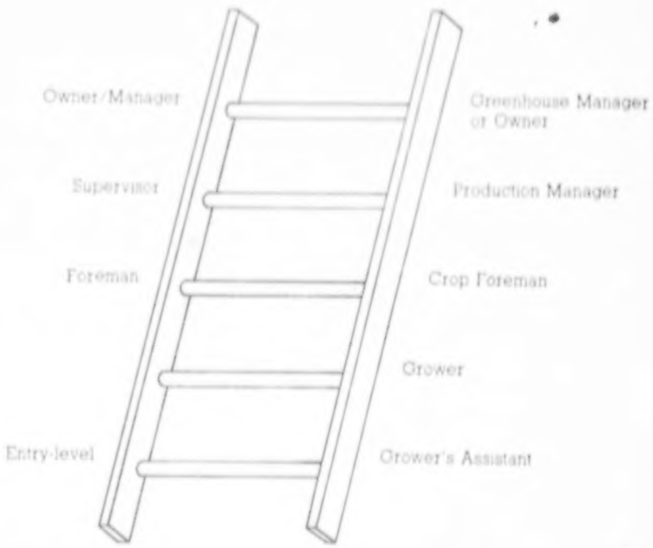
Career Opportunities in the Greenhouse Industry

There are many job opportunities in the greenhouse industry. Floriculture production is a very labor-intensive business. There will always be a need for workers who are willing to learn, accept responsibility, and get along well with other workers. Table 3.1, located at the end of this lesson, includes education requirements and work experience needed for some job opportunities in greenhouse operations.

Education does not end with the high school or college diploma. It is important to learn more about the chosen field by reading horticulture books, subscribing to professional business periodicals, and becoming a member who attends conferences sponsored by grower associations.

As with any business, one enters the greenhouse industry at the entry-level (i.e., grower's assistant, engineering crew member, or salesclerk). Advancement up the career ladder depends upon individual interests, experience, educational level, abilities, and personal goals. See Figure 3.3.

Figure 3.3 - Career Ladder


Owner/Manager
Greenhouse Manager or Owner
Supervisor
Production Manager
Foreman
Crop Foreman
Grower
Entry-level
Grower's Assistant

Each step requires increased skill and experience.

Summary

In general, the greenhouse grower produces a single floriculture crop and sells it himself or sells it to a wholesaler or wholesale greenhouse. The wholesaler, in turn, sells the crop and horticultural products to a retailer or retail greenhouse who sells them to the public. Many career opportunities are available in the greenhouse industry, specifically in the areas of business procedures, engineering, crop production, and marketing. The greenhouse career ladder has four rungs: (1) entry level as grower assistant, (2) grower or crop foreman, (3) crop production manager, and (4) owner/manager. As the greenhouse increases in size, its management structure becomes increasingly complex and more employees are required.

Credits

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TABLE 3.1 Career Opportunities in Greenhouse Operations

JOB TITLE	RESPONSIBILITIES	EDUCATION	WORK EXPERIENCE
Grower Assistant	Helps the grower perform tasks; May also work in maintenance or shipping; Usually seasonal work	High school student in vocational horticulture or high school graduate	Strong interest in crop production
Grower	Responsible for production practices for specific crops; All physical labor involved in producing a crop: soil preparation, planting, fertilizing, watering, pruning, pesticide application, harvesting, etc.	High school graduate with vocational or technical training; B.S. in horticulture	2 years experience as grower's assistant
Engineering Manager	Maintains all physical facilities; Supervises maintenance crews; plans work schedules; orders materials; and keeps records of scheduled jobs	High school graduate with vocational or technical training	Strong background in mechanical or agricultural engineering; Knowledge of crop production
Production Manager	In charge of growing the crops; Assigns duties and responsibilities to growers and assistant growers; Orders all plant materials & supplies for each crop;	B.S. or A.A. in horticulture	Several years experience as a grower; Knowledge of cultural techniques and market trends
Marketing Manager	In charge of grading, postharvest handling and storage, packing and shipping plants and flowers; Orders packing materials; Oversees sales and customer relations.	B.S. in business, marketing or business administration	Previous business experience; Knows greenhouse operations
Business Procedure Manager	Responsible for correspondence, payroll, bookkeeping, purchasing, and other financial arrangements; Supervises clerical staff	B.A. in accounting or business	Previous business experience
Manager or Owner	In charge of total greenhouse operations; Assigns duties and responsibilities; Coordinates production, marketing, engineering, and business procedures	B.S. in Horticulture.	Five years experience in crop production techniques, in business procedures, an[illegible] personnel management

Lesson 4: Greenhouse Parts, Structures, and Coverings

In order to grow plants, a good understanding of the physical structures used in production is required. Several different types of greenhouses and related structures are used in the production of flowers and plants. The characteristics of each type of greenhouse will be discussed in this lesson. The various types of covering or glazing materials for greenhouses and the parts that make up a greenhouse will also be presented.

A Greenhouse

A greenhouse is a structure covered with a transparent or semi-transparent material kept at a controlled temperature and used for the cultivation or protection of plants. A greenhouse provides an environment in which the grower can control the temperature, light, water, humidity, and plant pests. Because these environmental factors can be manipulated, a greenhouse is an ideal place to grow plants.

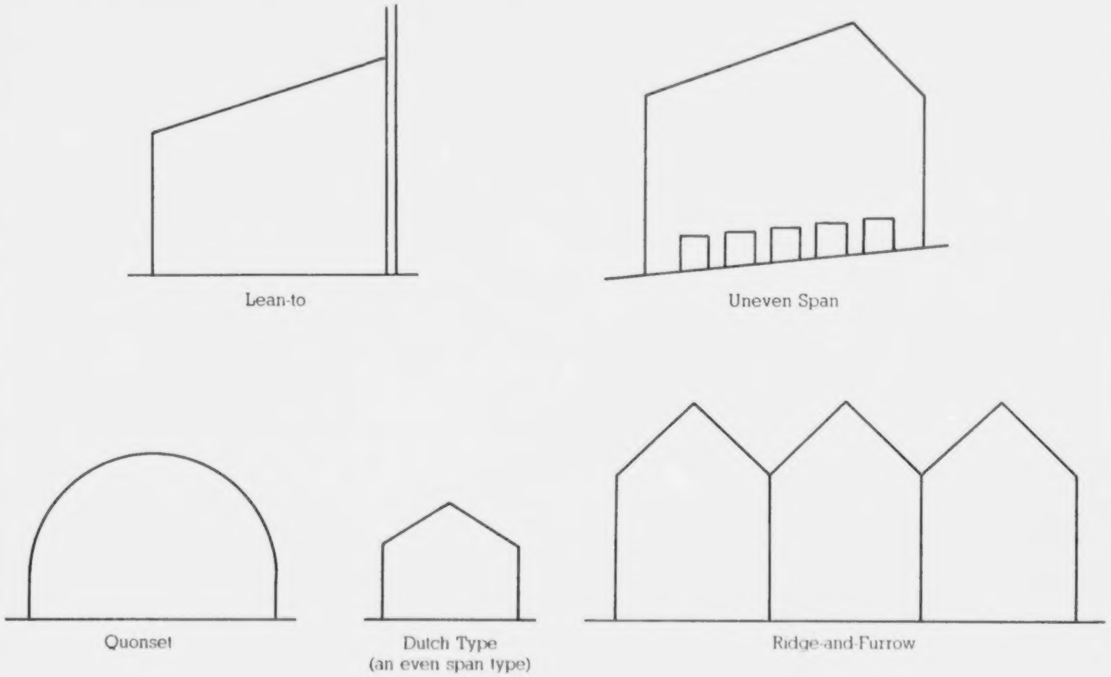
Major Types of Greenhouses

A greenhouse may be attached or free-standing. If attached, it is often a lean-to design placed against an existing building. Even span, uneven span, Quonset, Dutch, and ridge-and-furrow are self-supporting structures known as free-standing greenhouses. Figure 4.1 illustrates the different types of greenhouses.

A free-standing greenhouse built in Missouri should be oriented with the ridge running north and south so that light enters from a sidewall rather than an end wall. This orientation makes the best use of winter light and reduces shadows within the greenhouse.

For proper ventilation, cooling, and lighting, the distances between free-standing greenhouses vary according to the direction of the ridge cap. East-west free-standing greenhouses are usually

Figure 4.1 - Types of Greenhouses



spaced 10-12 feet apart. North-south greenhouses can be spaced 5-6 feet apart.

The selection of the type of greenhouse varies according to a number of factors. Crops to be grown, covering material, size of the greenhouse range, cost of construction and materials, climatic conditions, heating source, and topography are some factors to consider. Some of the characteristics of each style are discussed below.

Lean-to or shed-roof - This style of greenhouse is located against the side of an existing building. It should be attached to an east- or south-facing wall and is primarily used for teaching, research, a hobby, or a propagating structure.

A lean-to greenhouse makes good use of sunlight. The adjoining building minimizes the requirements for roof supports. Generally the heating for an attached greenhouse can be provided by the adjacent building. This style of greenhouse has become very popular recently as a room addition to homes and businesses. It is also a way to incorporate passive solar heating into an existing building. However, an attached greenhouse can provide only a limited area to raise plants.

Even span or span roof - A free-standing even span greenhouse has two roof slopes of equal pitch and width. The Dutch type greenhouse is a popular style of an even span greenhouse. Many commercial growers use this style of greenhouse. Since the even span greenhouse is a separate building, it offers excellent light, ventilation, and temperature control for crops. Better cultural controls can be obtained by separating crops into different greenhouses. An even span greenhouse is easy to cover with glass, fiberglass, or plastic.

Uneven span - This style of greenhouse is not as common. An uneven span greenhouse is usually constructed on a south-facing hillside with the short side of the roof on the uphill side of the slope. The uneven span is usually a larger greenhouse with minimal shadows and is generally covered with glass.

When this style of greenhouse is built on a south-facing hill, it conserves energy. Since it is built on a hillside, the uneven span greenhouse uses ridge and side ventilators to its advantage, decreasing cooling and heating costs. Unfortunately, being constructed on a slope makes it difficult to work in and hinders it from being adapted for automation.

Quonset - This free-standing style is the most popular today. The Quonset has a semicircular arch that starts either at the ground or on top of a sidewall. It can be constructed in various widths and lengths and can be covered with a plastic film or fiberglass. There are no interior posts and the roof is not pitched. A Gothic arch greenhouse is a modified Quonset which comes to a peak at the ridge cap.

The Quonset is very economical to construct and has few shadows. Because of the shape of the greenhouse, there is reduced wind and snow load. One disadvantage of the Quonset greenhouse is the wasted area along the sidewalls.

Dutch - This type of even span greenhouse is becoming very popular. It has a low gable, making it more economical to heat. It is easily covered with plastic or glass. Because these greenhouses are usually wider and longer than lean-to houses, interior space can be better utilized. The Dutch greenhouse can be constructed with six-foot-high sidewalls to reduce the unusable space along the sides. This style is also free of interior support posts, so labor-saving equipment and machinery can be easily adapted within the greenhouse.

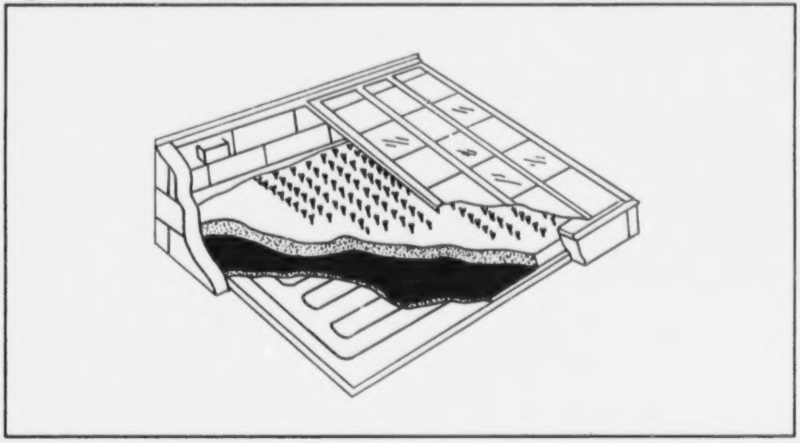
Ridge-and-furrow - This style allows for maximum use of land by connecting several greenhouses along the length of their eaves. The sidewalls are eliminated between the row of greenhouses, creating a large interior growing area covered with one roof. Because of the increased interior growing area, labor-saving equipment and machinery may be used within the greenhouse to implement automation. As a result, this style is often used by large commercial growers and is the most common style used when constructing a greenhouse range. Because many of the sidewalls have been eliminated, heat loss through exterior walls is reduced. The elimination of walls also makes construction less expensive. Ridge-and-furrow greenhouses are easy to cover with glass, fiberglass, or rigid plastic.

Related Structures

Outside structures such as coldframes, hotbeds, and lathhouses can be used to start seedlings of nursery stock, root deciduous and evergreen plant cuttings, precool florist plants, and produce plants during hot summer months. The use of these structures will depend on the season of the year that the structure will be used, plant specie grown, initial cost, and operating expense.

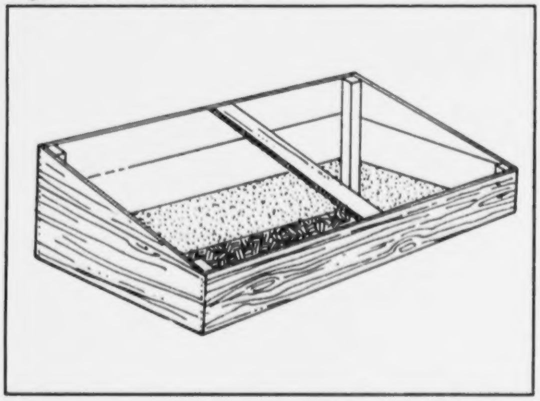
Coldframe - A coldframe is an unheated outdoor growing structure covered with a transparent glazing material. It is used to protect or harden plants from frost. It may also be used for starting plants in late spring, summer, or fall when no additional heat is needed. Coldframes use only the sun as a heating source.

Figure 4.3 - Hotbed Construction



A coldframe consists of a large wooden box or frame with a sloping, tight-fitting lid covered with glass, fiberglass, or plastic film. The coldframe should be located where the sash slopes down from north to south and in an area protected from winds. To produce plants in a coldframe, care must be taken to provide ventilation, shading, watering, and winter protection. See Figure 4.2.

Figure 4.2 - Coldframe



Hotbed - A hotbed is an outdoor growing structure similar to a coldframe but heated by a source besides the sun (e.g., steam, hot water, electricity, or manure). Hotbeds are usually used for the same purpose as a greenhouse but on a much smaller scale. Early in the season, hotbeds are used to start seedlings and to root leafy cuttings.

An artificial heating source (e.g., electrical heating cables) is used under the propagating media. The details of a hotbed can be seen in Figure 4.3. The heating source is covered with a wire netting. Then four to six inches of propagating media or flats filled with media are placed on top of the netting.

The wooden frame should be made of decay-resistant wood such as redwood. cypress, or cedar - none of which need to be treated with a wood preservative. All other types of wood should be treated with a wood preservative (e.g. copper naphthanate, zinc naphthanate or Cuprinol, chrome copper arsenate or CCA, or latex paint) to enhance longevity.

Lathhouse - A lathhouse is a structure shaded by lath or other material for the purpose of year-round production of plants in warm climates or during summer months in locations of warm temperature and high light intensity. A lathhouse is fueled by the sun.

A lathhouse is commonly constructed as a pole-supported structure covered with lath, polypropylene shade fabric (Saran®), or other material. The south-facing side is also covered with the shade material to provide protection from the sun.

Purchasing a Greenhouse Covering Material

Several greenhouse covering materials are available. Some factors to consider when selecting a covering material are initial cost, maintenance costs, durability, light transmission, heat retention, superstructure required, water condensation potential, expansion/contraction potential, light diffusion, static electricity charge, and the availability of materials.

Major Greenhouse Covering Materials

Rigid coverings and flexible coverings are the two basic types of greenhouse covering materials.

There are four types of rigid greenhouse covering materials: glass, fiberglass, acrylic, and polycarbonate. Polyvinyl chloride, polyvinyl fluoride film, and polyethylene are flexible greenhouse covering materials.

Glass - This type of covering material is placed on the greenhouse much like shingles on a home. The panes of glass are lapped about one-fourth of an inch. Standard B grade, 26-ounce double strength glass is most commonly used. Dutch houses use a slightly thicker, triple-strength glass. The pane width varies from 16 to 20 inches.

Glass has excellent light transmission at 91 to 97 percent. It also has high heat loss. Glass experiences little thermal expansion and contraction. It is readily available and long-lasting, with a life of 25 years or more. However, glass is breakable, expensive, and difficult to work with. Because it is heavy, glass requires a substantial superstructure.

Fiberglass - The proper name for fiberglass is fiberglass reinforced plastic (FRP or GRP). This covering material has glass fibers imbedded in plastic resins. The corrugated panels weigh 4 to 12 ounces per square foot. A five ounce weight is recommended for greenhouse roofs. The best grades of fiberglass have Tedlar® film bonded to the exterior surface. The film slows down the clouding of the fiberglass and allows for better light transmission for a longer period of time. Fiberglass has light transmission equal to or better than glass (depending on grade), but better diffusion of light.

Fiberglass is 19 percent easier to cool than glass. Its heat requirements are about the same as glass. When periodically resurfaced, fiberglass lasts 10 to 20 years. However, it may become cloudy in appearance as it ages. Because fiberglass burns very rapidly, insurance costs are high.

Acrylic - Acrylic (also known as Plexiglass®, Lucite®, and Exolite®) is manufactured in double-walled sheets with air space between the walls, thus giving it greater insulation value than glass. Although it is lightweight, it has superior resistance to ultraviolet light. This material does expand and contract, so installing allowances need to be made. A new non-drip double acrylic is available that eliminates condensation problems and increases light transmission by 10 percent. Acrylic is weather resistant and twice as impact resistant as glass. It has high light transmission. Acrylic is expensive, easily scratched, and flammable.

Polycarbonate - Polycarbonate (also known as Lexan®) consists of profiled sheets that have double-walled construction with airspace between the walls. It is easy to install, weighing one-sixth the weight of glass and one-third the weight of acrylic.

An advantage of polycarbonate is its impact strength. The non-flammable, textured surface prevents condensate drip and diffuses light. Polycarbonate has slightly lower light transmission than acrylic, but similar heat retention. It is slightly more expensive than acrylic and fiberglass. Polycarbonate has poor ultraviolet light resistance and scratches easily. It has a high expansion/contraction potential.

Polyvinyl chloride (PVC) - PVC is slightly more durable than polyethylene and three to five times more expensive. PVC is only available in narrow widths; however, an 8 mil to 12 mil thick sheet will last four to five years. It has an electric charge which attracts dust and reduces light transmission. PVC has a high potential for moisture condensation. The PVC film does not break down when exposed to ultraviolet light, but it becomes brittle and easily torn in cold weather. PVC is flammable and not widely used.

Polyvinyl fluoride film (Tedlar®) - Polyvinyl fluoride film is a highly durable covering that can withstand weathering for 10 years. It has excellent light transmission. It is five times more expensive than polyethylene, but because of its lasting quality, the annual cost is less than polyethylene. It is available only in narrow sheets, making installation costly and time consuming. This film is resistant to ultraviolet deterioration.

Polyethylene - This is the most commonly used and least expensive covering material. A four- to six-mil grade polyethylene (poly) film is recommended to cover wood or metal greenhouses. The poly can be purchased with a centerfold or gusseted. It is available in sizes large enough to cover an entire greenhouse with one piece. In order to save on heating, a double layer of poly with an inflated airspace between the layers retains 33 to 40 percent more heat than glass alone. While trapping heat, it also traps humidity, so moisture condensation potential is high. Because poly houses are so tight, CO_2 does not flow in freely.

This material does break down when exposed to ultraviolet light. When an ultraviolet-inhibitor is added to poly film, this breakdown time can be extended from one year to three years before replacement is required. Polyethylene is quick and easy to install.

Although this discussion centers on covering materials, it must be remembered that the superstructure, or supporting framework, must be properly constructed. Both covering and superstructure are integral parts of a greenhouse. The superstructure must have adequate structural strength to support the roof under maximum load. This load includes the weight of the superstructure and covering material, weight of ice and snow, lift caused by wind acting on the covering, and the weight of maintenance workers.

Three types of material used as superstructures for greenhouses are wood, galvanized steel pipe, and aluminum. The type of superstructure selected will depend mainly on the covering material chosen. For example, the superstructure for a greenhouse covered with glass or fiberglass must be stronger than one covered with plastic. The trusses on film-covered houses can be spaced farther apart because the plastic film is supported or attached to purlins that run from truss to truss. A greater number of purlins are needed in a plastic house. In addition, it is recommended that a free-standing support system (e.g., metal piping) be built to accommodate hanging baskets. This will prevent the additional weight from causing the greenhouse to collapse.

The Parts of a Greenhouse

In order for the greenhouse worker to construct or maintain a greenhouse it is important to know the parts of a greenhouse. Figure 4.4 illustrates and names each part of a greenhouse.

Sidewalls and gable ends

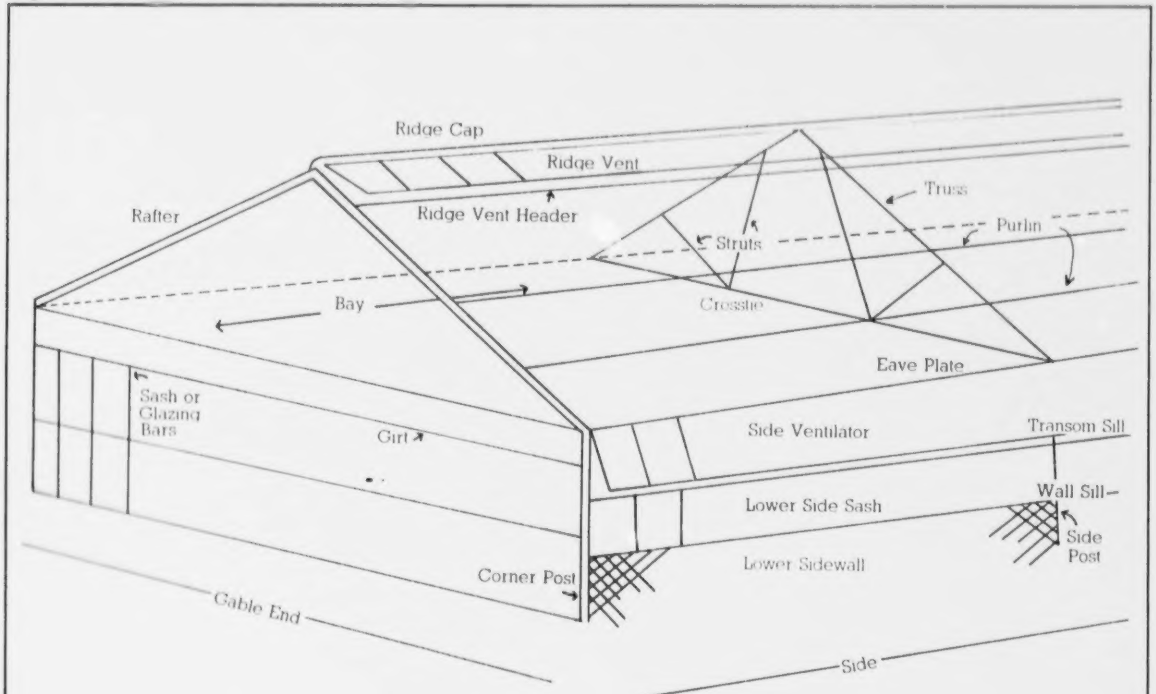
Bay - a lengthwise section of greenhouse between two vertical side posts or other structural members

Column - an interior structural support

Crosstie - a structural member fastened between columns

Bay plate - the longitudinal member of the intersection of the side and roof of the greenhouse

Figure 4.4 - The Parts of a Greenhouse


Ridge Cap
Ridge Vent
Rafter
Ridge Vent Header
Truss
Purlin
Struts
Bay
Crosstie
Eave Plate
Sash or Glazing Bars
Girt
Side Ventilator
Transom Sill
Wall Sill
Lower Side Sash
Side Post
Lower Sidewall
Corner Post
Gable End
Side

Girt - similar structure as purlin, only in sidewall

Glazing bar (sash bar) - the member on which glass is placed

Post (side, gable, partition) - the structural member set in ground for support of the greenhouse

Sash - a movable framework of glass, fiberglass, or other glazing materials

Sash stop (vent stop) - the member against which the ends of the sash closes

Side ventilator (transom sash) - the hinged structure at eave plate which closes on transom sill

Transom sill - the member located between the wall sill and the eave plate

Wall sill - the member on top of the greenhouse wall, along sides and gables

Roof structures

Purlin - longitudinal supports for roof bars which fasten at each end to truss or gable rafters

Rafter - the top member of truss running from the eave to the ridge

Ridge - the member at peak of roof extending from end to end of the house

Ridge cap - the member located on top of the ridge

Ridge vent header - the member on which ridge vents set

Ridge vent - the structure below the ridge that opens for ventilation

Strut - the member of the truss designed to receive pressure or weight in direction of its length attached to the rafter

Truss - the framework fastened together and supported on top of the side posts which gives the main interior support to the greenhouse

Summary

Many types of greenhouse architectural styles are available, both attached and free-standing. Some greenhouse-related outdoor growing structures are cold frames, hotbeds, and lathhouses. Choice of greenhouse covering or glazing materials is very important. Rigid covering materials include glass, fiberglass, acrylic, and polycarbonate. Flexible coverings include polyvinyl chloride, polyvinyl fluoride, and polyethylene. Greenhouse structural parts located in sidewalls and gable ends, as well as roof components, were discussed. All of the above factors must be considered when building, purchasing, or even working in a greenhouse.

Credits

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Environmental controls in the greenhouse are very important. The proper environment must be provided for optimum plant growth and development. Some of the environmental controls needed in a greenhouse are ventilation, heating, cooling, irrigation, and air circulation. In order to produce quality plants, it is important to understand how the environmental controls work.

Purposes of Ventilation

Side and ridge ventilators, forced-air fans, and perforated convection tubes can be used to ventilate a greenhouse. These ventilation methods are used to reduce temperature, introduce fresh air into the greenhouse, and reduce the relative humidity as a means of controlling diseases.

Equipment for Ventilation

Ridge and side ventilators - Ventilators take advantage of natural air movement. As air heats up, it becomes less dense and rises; this is known as the "chimney effect." The hot air rises to the top of the greenhouse, and if the ridge ventilators are open, the hot air escapes. Additional sidewall ventilators will increase the airflow. See Figure 5.1. The ridge and side ventilators can be operated either manually or by a power system. The vents can be opened manually by using hand cranks, chain pulls, or levers functioning independently or attached to gear-driven units. Gear-driven units may be connected to vents by elbow arms or rack-and-pinion devices. A thermostat can be connected to the power-driven system, making it completely automatic.

Forced-air fans - Fans are often used to ventilate greenhouses. Fresh air replaces the hot air being pulled out by the exhaust fans. See Figure 5.2. Forced-air fans can be used to ventilate in late spring, summer, or early autumn. A thermostat is connected to the fans to automatically regulate their action.

Perforated convection tubes - Overhead perforated convection tubes running the length of the greenhouse can be used for ventilation. During the winter, they enable extremely cold air to be used for ventilation purposes in the greenhouse without causing injury to the plants. Fresh air enters through motorized louvers and is blown by fans through a perforated tube. If dehumidification is desired, the cold air is heated by a unit heater before being distributed through the openings in the convection tube. See Figure 5.3.

Figure 5.1 - Ridge and Side Ventilators

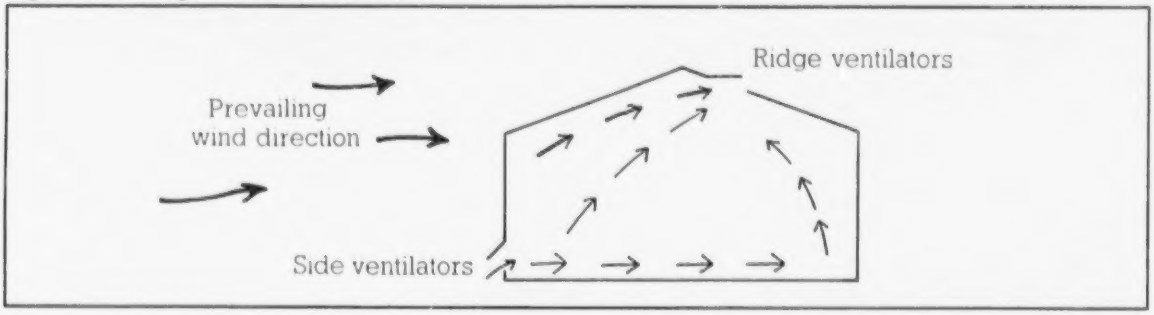


Figure 5.2 - Forced-Air Fans

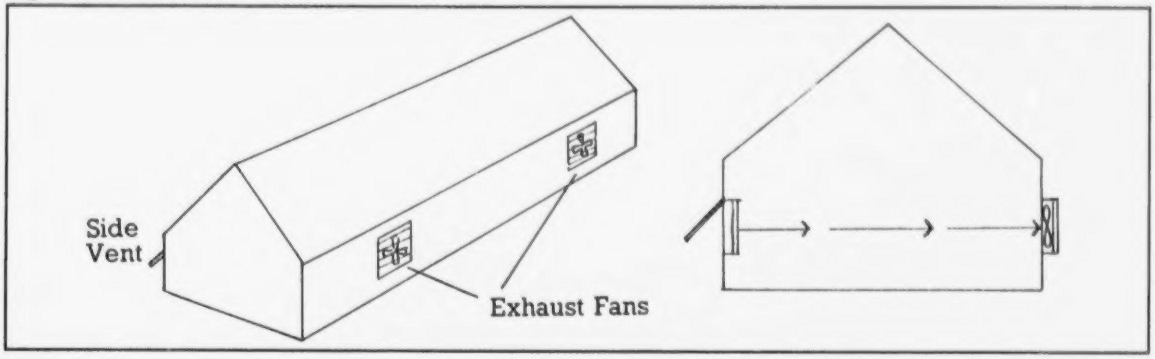
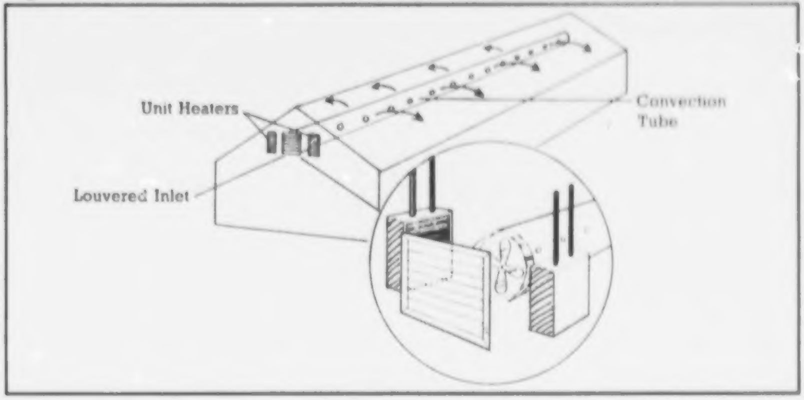


Figure 5.3 - Convection Tube



Methods for Heating a Greenhouse

Although the sun does provide some heat for a greenhouse, it cannot be relied upon to deliver a constant source of heat. A secondary heating system must also be used.

The fuel used to provide the energy to heat the greenhouse is a very important consideration when selecting a heating method. The choice of fuel for a greenhouse depends on the cost per Btu (British thermal unit: heat required to raise the temperature of one pound of water one degree Fahrenheit), the availability of the fuel, transportation costs, equipment costs, automation, and labor costs.

The secondary methods of heating a greenhouse are boilers, unit heaters, and radiant heaters. Boiler systems are used to heat large greenhouse ranges using steam or hot water as a delivery medium. Unit heaters, often used in smaller greenhouses, burn fuel to produce heat directly. Radiant or infrared heating systems emit infrared radiation. Plants, benches, and people absorb this electromagnetic energy which is converted to heat, but the air is not heated.

An emergency generator and/or heater is also necessary in case of failure of the secondary heating source.

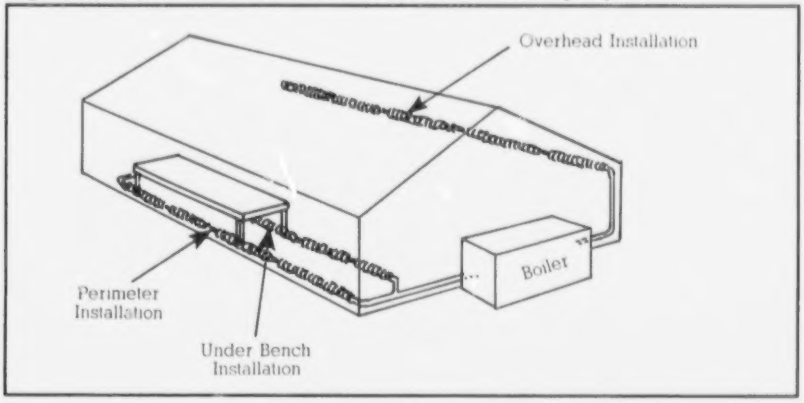
Equipment for Heating

Boilers - Boilers are made of either steel or cast iron. Boilers burn coal, No. 2 oil, kerosene, LP gas, or natural gas to heat water. Steam or hot water is then distributed throughout the greenhouse by pipes. See Figure 5.4. The pipes return the cooled water to the boiler to be reheated. The pipes used to distribute the heat from a boiler may be located along the side walls, overhead, or under the benches.

Usually a steam heating system is used when the greenhouse has an area of at least 15,000 sq. ft. A steam system uses smaller mains than a hot water system. The pipes that are used as the mains in a steam system are one and one-half inches in diameter. One linear foot of steam pipe distributes 180 Btu/hour.

Greenhouses equipped with a boiler may also be heated with hot water. In general, a hot water system is used when the greenhouse has an area of less than 15,000 sq. ft. The water is heated to about 180°F (82.2°C). A hot water system uses larger mains; all of the pipes are two inches in diameter. Each linear foot of hot water pipe distributes 160 Btu/hour.

Figure 5.4 - Steam or Hot Water Heat Distributed by Pipes



Unit heaters - To heat a greenhouse, unit heaters can operate independently or off a steam or hot water system. The unit heaters heat air which is then distributed by fans. Unit heaters can also be attached to convection tubes, and such a setup is called a perforated convection tube heater/fan system.

LP or natural gas is used to fuel 90 percent of all unit heaters. No. 2 oil fuels nearly all the rest, although kerosene, steam, or hot water could be used.

When operating a unit heater that uses fossil fuel, oxygen is consumed to burn the fuel. However, incomplete burning of fossil fuel can result in the release of toxic gases into the greenhouse. Ethylene gas, for example, can cause damage to both plants and people. Toxic fumes are especially hazardous in poly houses that are tightly sealed. Because of this, it is important that unit heaters be provided with adequate oxygen intake. A general rule can be used to insure proper fresh air intake: one square inch of outside opening should be provided near the heater for every 2,000 Btu capacity of the heater. Also, the unit heater must have proper venting to allow toxic gases to be exhausted from the greenhouse.

Radiant - Infrared radiant heaters are placed overhead the length of the greenhouse 20 - 30 feet apart. The radiant heater produces high-temperature air by vacuum combustion. The radiant heater is fueled by LP or natural gas. In smaller greenhouses it may run on electricity. The air is pumped through two-inch pipes to radiate heat downward to the plants. Radiant heat is 93 percent efficient and has the lowest operating fuel bill. There are no condensation or humidity problems with radiant heat.

Emergency heaters and generators - In the event of an electrical power failure or heater failure during cold periods, it is important to have emergency heaters and generators to prevent crop loss due to chilling. A standby electrical generator is a must for any greenhouse operation, especially when there is only one heater or one boiler in a greenhouse. Some growers use portable gas burners as the back-up heating source; they must be maintained in working order. An adequate supply of fuel must be kept on hand in case the need arises.

Cooling a Greenhouse

Temperatures inside the greenhouse can be 20°F (11°C) higher than outside, even with side and ridge vents open. There are four methods that are used to cool a greenhouse: ventilation, forced-air, evaporative cooling, and shading.

Ventilation - Hot air rises naturally and escapes from the greenhouse through the ridge and side vents. This natural ventilation is also known as the "chimney effect."

Forced-air system - Fans are used to pull outside air through the greenhouse and exhaust air already in the greenhouse. Consequently, the forced-air system may be considered as ventilation by pulling in cool air with the help of fans to move the air more effectively.

Evaporative cooling system - A wet pad is added to the greenhouse forced-air system to increase the cooling effect of the fans. This is possible because energy is required to evaporate water. This energy comes from the air, resulting in lower air temperature. The pads are made of excelsior, crossfluted cellulose that looks like corrugated cardboard, expanded aluminum, or spun plastic. The excelsior pads will last one year, and cross-fluted cellulose material may last for ten years, depending on water quality. The aluminum pads are more expensive, but they do not need to be replaced, but must be kept clean. The initial investment for plastic pads is high, but because they last several years the overall cost is relatively low. Plastic pads need to be maintained properly.

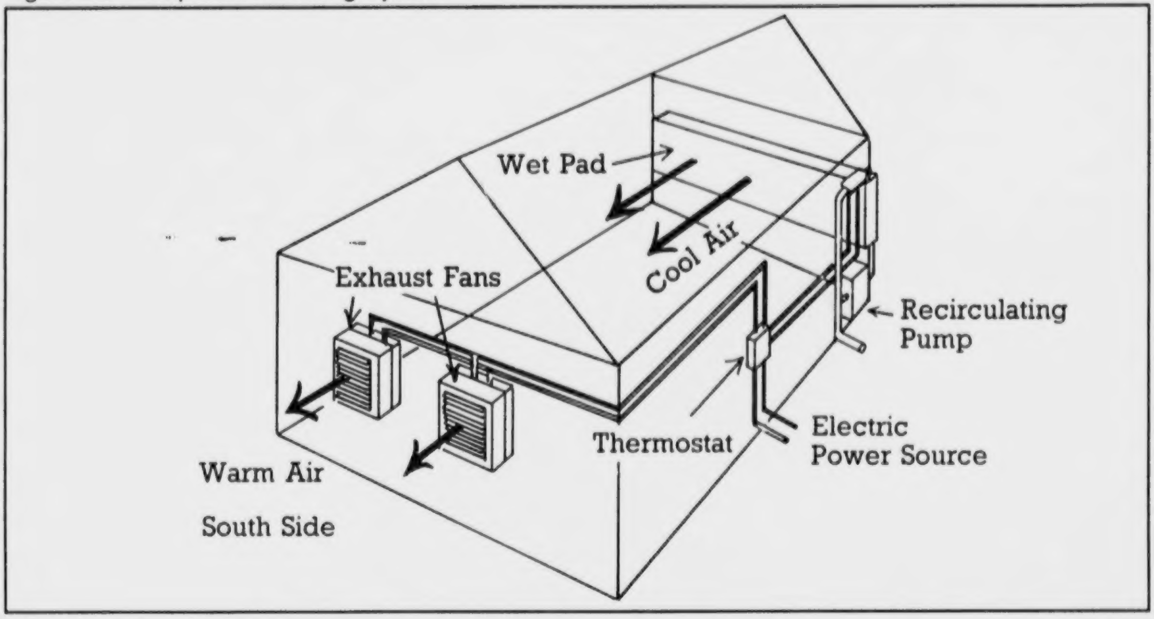
Wet pads are placed either inside or outside the side vent. The pads should be installed on the prevailing wind side of the greenhouse in such a manner that all air entering the greenhouse must pass through the pads. The cooling pads are kept moist. Forced air fans are mounted in the greenhouse wall opposite the cooling pads. See Figure 5.5. The fans pull air through the cooling pads. The air enters the greenhouse cooler than the outside temperature; the amount of temperature drop depends on the temperature and humidity of the outside air. The maximum amount of cooling possible is achieved by the evaporative cooling system.

Shading - Whitewash, commercial shading compounds, or shade cloth are applied atop the greenhouse covering material to reduce the light intensity, especially during the summer months.

Reasons for Air Circulation

Air circulation is a major concern for the greenhouse owner. The main reason to circulate air is to improve heat distribution. Air circulation also reduces the relative humidity in conjunction with other equipment; this will reduce plant diseases. In addition, air circulation increases the rate of

Figure 5.5 - Evaporative Cooling System



carbon dioxide replenishment around the leaf surface.

Methods of Air Circulation

There are two methods of circulating air in a greenhouse: turbulator fans and perforated convection tube heater/fan system. Turbulator fans that move large quantities of air at relatively slow velocities are preferred for greenhouse air circulation. These circulation fans are installed overhead to move the air outward and downward. Air circulation fans should be in continuous operation, except when the cooling system is working.

Convection tubes are used for air circulation as well as for ventilation, heat distribution, reduction of relative humidity, and a minimum amount of cooling in winter. The tube system runs the length of the greenhouse overhead and distributes air through perforated openings. The fan on the heater/fan system attached to the convection tube pushes air the length of the tube. Fans should be operated continuously to pump the air through the tubes.

Methods of Irrigation

Watering or irrigating has a direct effect on the quality of plants produced. Many different irrigation systems have been developed for greenhouse crop production. Irrigation can be done by hose manually or by use of an automatic irrigation system.

Manual watering with a hose is the most common method of irrigation and the most expensive to operate. There must be a conscientious person watering to prevent variation. This person has a direct and significant effect on the quality of plants produced. Manual watering offers easy adaptability to various moisture needs of different crops. Automated systems greatly reduce labor costs and hence are quite popular. Most automatic watering systems last three to ten years.

Equipment for Automatic Irrigation

Many different automated irrigation systems have been developed for greenhouse crop production. In addition, automatic watering controls are often used to regulate the irrigation systems.

Automatic watering systems - The five categories of automatic watering systems are overhead, bench level, drip, and subirrigation.

Overhead watering systems consist of irrigation from a source above the plants. Figure 5.6 illustrates one type of hanging sprayer system, which is a common overhead system in which 360° nozzles suspended five feet apart apply a heavy mist in a circular spray pattern.

Spray-stakes can also be used for overhead watering. Spray-stakes are used for container-grown plants or bench crops. Nozzles are pointed up and are supported on stiff stakes set into the bench. See Figure 5.7. The support stakes come in heights from 10 to 36 inches depending on the height of the crop. The tubing that is used to connect the nozzles to the water main runs down the center of the bench. Nozzles are available with a spray pattern of 180° and 360° with an eight-foot diameter.

Bench level irrigation is another automatic watering system. Plants can be watered using

Figure 5.6 - Hanging System

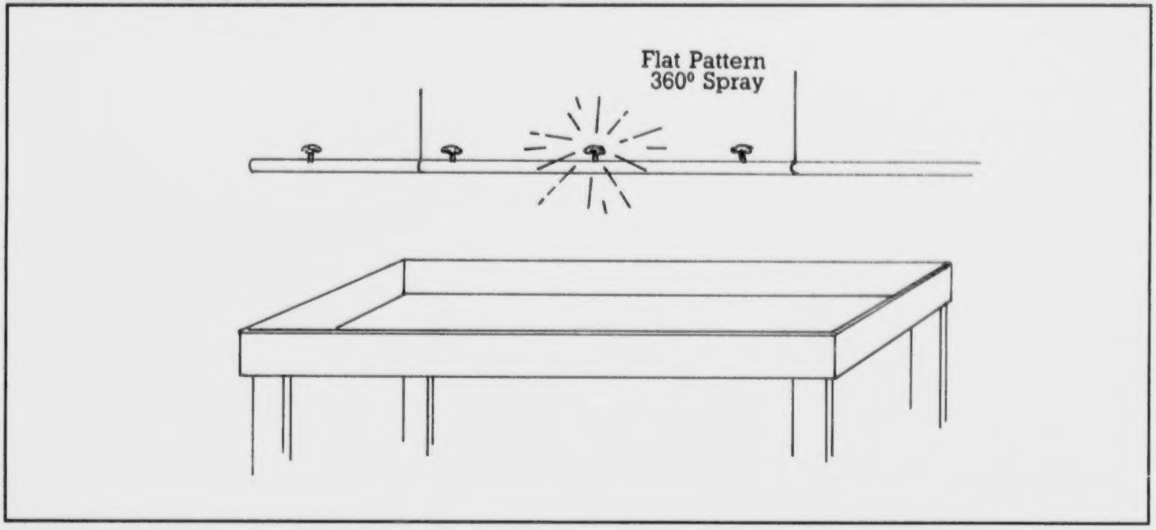
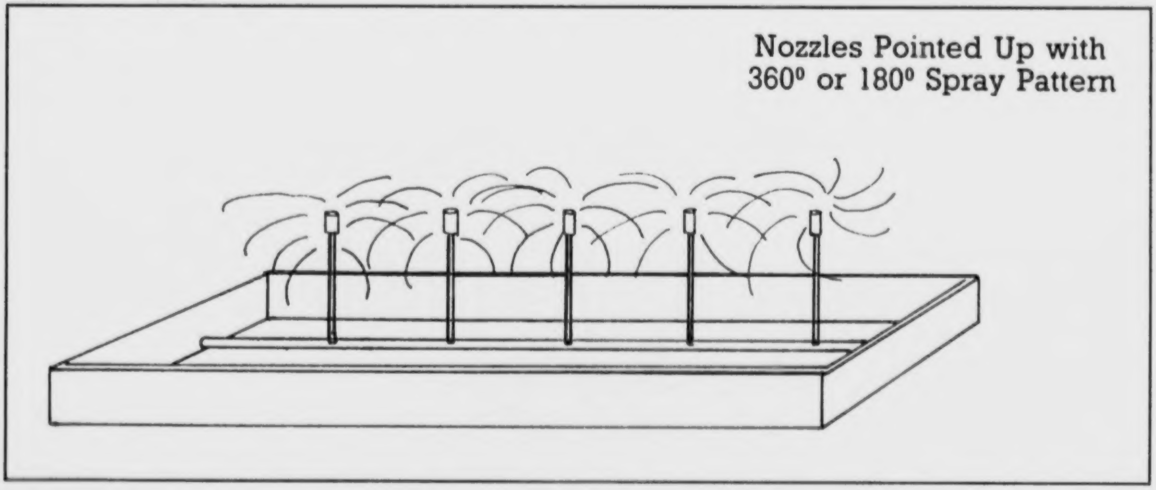


Figure 5.7 - Spray-Stakes



either a center-of-bed discharge system or a perimeter discharge system. In the center-of-bed system, the water main, which runs down the center of the bench, contains nozzles that are placed three feet apart and two inches above the soil. These nozzles water in a flat spray pattern. In the perimeter discharge system, the water main that is placed around the perimeter of the bench contains nozzles that are spaced two to three feet apart. See Figure 5.8. These nozzles discharge water in a 180° pattern.

Spaghetti tube, water loop, ooze, and drip hose are all types of drip systems. In the spaghetti tube system, individual pots or hanging baskets are watered with narrow diameter tubing that is connected to the water main on each bench. Figure 5.9 illustrates the numerous tubes of the spaghetti tube system. A weighted end keeps the tube from falling out of the pot. A manual or automatic watering valve measures the water applied to container-grown plants. Water loops are circular loops of perforated plastic that are placed around the stems of plants. See Figure 5.10. Five sizes of loops are available with diameters of 5 to 16 inches.

Figure 5.8 - Perimeter Watering System

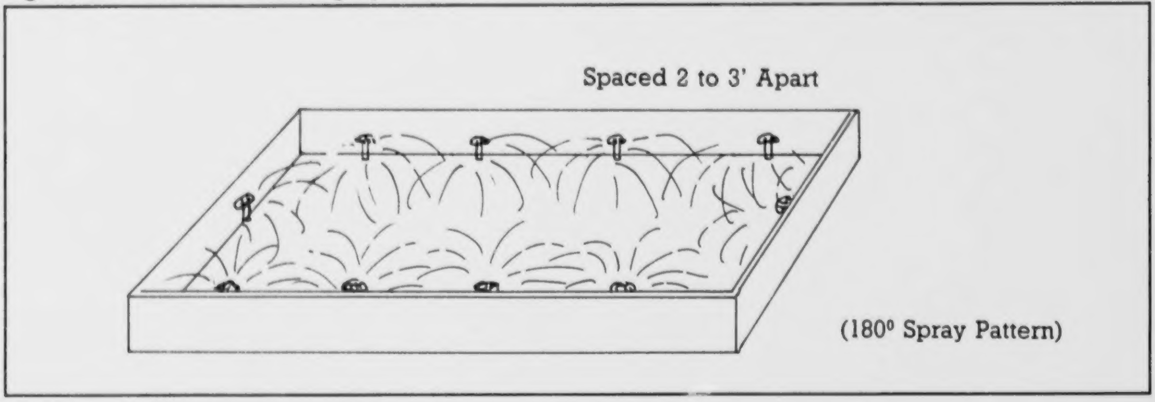


Figure 5.9 - Spaghetti Tube System

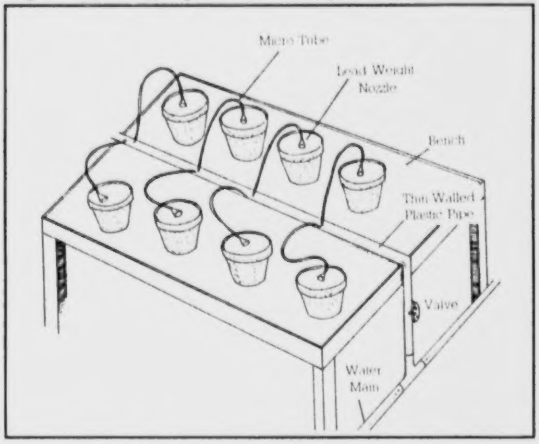
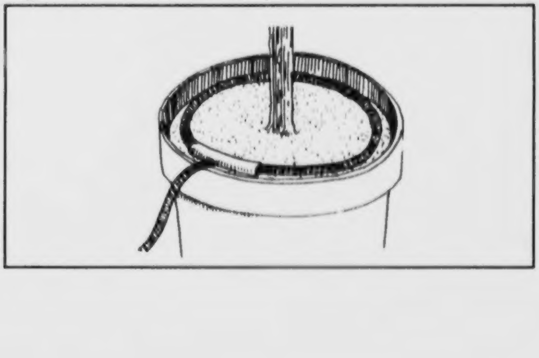


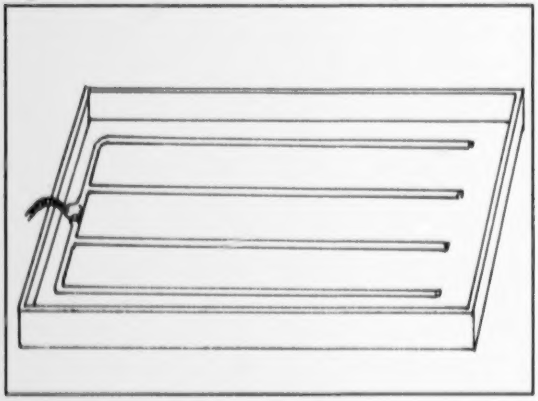
Figure 5.10 - Water Loops



An ooze system is another type of automatic drip watering system for bedded crops. Ooze systems consist of 3/4-inch porous plastic hoses that "ooze" or leak water along their length. Ooze hoses are spaced 8 to 12 inches apart and run the length of the bench. The drip hose method is similar. Twin-walled flexible plastic hoses, which are one inch in diameter, are placed 8 to 12 inches apart down the length of the bench. Water drips into the soil from the water outlets spaced 12 inches apart. See Figure 5.11.

Another category of automatic irrigation includes the sub-irrigation systems. Capillary mats, embedded ooze systems, and ebb and flow systems are three types of in-bench watering methods. Capillary mats are ideal for small containers or crops grown in plastic pots such as African violets. Black plastic is placed on the bench and covered with fine sand or a capillary

Figure 5.11 - Ooze or Drip Hose Layout



mat. Water is distributed on the mat by an ooze system. The mat is continuously wet. After a plant is placed on a capillary mat, its first watering should be from the top to establish the capillary action. Then water will be drawn up from the mat into the pot's bottom holes. See Figure 5.12.

In an embedded ooze system, a porous plastic foam hose is buried in the soil. Water seeps out through the pores in the plastic. Two lines are used in a four-foot bench. In ebb and flow systems, a waterproof bench forms a reservoir, which is flooded with several inches of water. The pots are placed in the bench. The excess water is allowed to drain away and is recycled later.

Automatic watering controls - Automatic irrigation systems generally will use some type of automatic watering control to start and stop the flow of water. Some of the automatic watering controls are flowage, pilot pot, and timer.

The flowage method can be used to regulate irrigation. A small amount of water flowing into the irrigation system is diverted into a container. After a predetermined quantity or weight of water has accumulated in the container, the system shuts off.

A sensor can be placed in the base of a calibrated pilot pot. This sensor will shut the water off when the soil mass becomes heavy enough. A timer or a series of timers can be used to turn the irrigation system on and off at predetermined intervals, usually a certain number of minutes.

Other Greenhouse Equipment

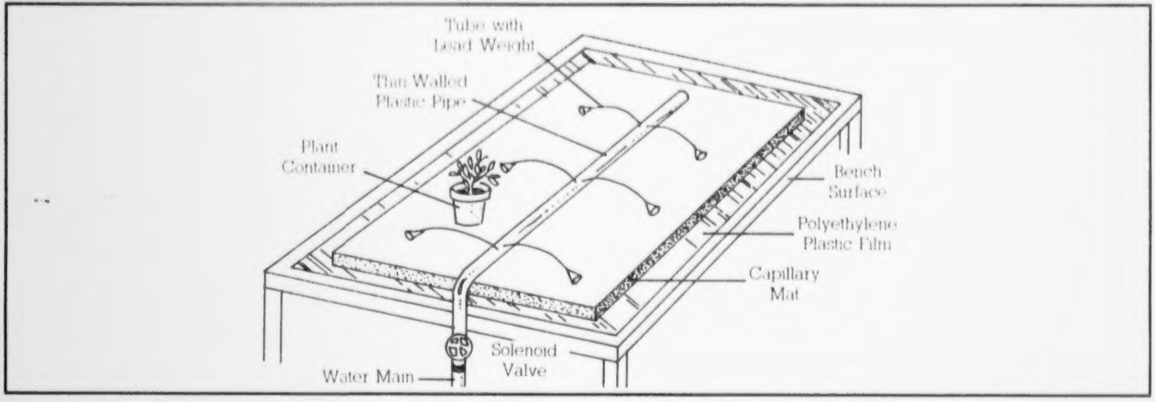
Propagation bed - A propagation bed is an enclosed frame within the greenhouse. It is covered with glass or plastic and contains propagating media and an automatic mist system, as well as an under-media heat source. This provides an area with high enough humidity to allow cuttings to root without wilting.

The automatic mist system contains nozzles that produce a fine mist which is suspended over the propagation bed. These nozzles are controlled by time clocks or other electronic timing devices so that a small amount of moisture is released over the cuttings periodically during the day.

Care must be taken to avoid a build-up of disease organisms in the propagation bed. The propagation bed is the ideal environment for bacterial and fungal growth. It is important that all materials used in this bed be clean. Periodic steam treatments of the propagation bed and/or additional applications of fungicides are necessary.

Carbon dioxide generators - By increasing the amount of carbon dioxide in the greenhouse air, an increased rate of growth and development for

Figure 5.12 - Capillary Mats



plants results. Carbon dioxide is needed by plants only during the daylight when photosynthesis is occurring.

The most common way of increasing carbon dioxide in the greenhouse air is by combustion of gas or oil in burners. These burners are called carbon dioxide generators. By using carbon dioxide generators, the carbon dioxide concentration in the atmosphere can be increased from a natural level of 300 ppm to 1,000 ppm or more.

Fertilizer proportioners - Liquid fertilizer concentrate can be added to water as it is used to irrigate the plants. There are two types of proportioners to mix and distribute the concrete: injectors and siphons. The injector proportioners inject a uniform volume of liquid fertilizer concentrate into a unit volume of irrigation water.

The siphon proportioner creates a pressure difference by routing the irrigation water through a reduced-sized pipe or orifice. A variable amount of fertilizer concentrate is proportioned into the irrigation water depending on the rate of water flow and the water pressure.

Photoperiodic control - Photoperiodism is the influence of the length of daylight versus night length on plant growth. Plants will grow vegetatively or produce flower buds depending upon photoperiodism. By regulating the day length, growers can often produce flowering plants year-round. Photoperiodic control can be achieved by either extending the day length by using artificial lights or by decreasing the day length by using shade cloth, depending upon the photoperiodic response of the plant species.

Extending the day length can be used to regulate flowering. Incandescent light bulbs can be used to increase the day length. A minimum of 10 foot-candles of light at plant tops is recommended for this purpose. Lighting can be done three ways: extending the day, continuous lighting in the middle of the night, or cyclic lighting. It is more economical to interrupt the night than to extend the day. An example of continuous lighting in the middle of the night would be light provided every night from 10 p.m. to 2 a.m. Cyclic lighting is intermittent lighting six minutes out of every 30 minutes for four hours from 10 p.m. to 2 a.m.

Decreasing the day length is another method of photoperiodic control. To shorten the day length, black cloth is used to exclude all light. The black cloth or special plastic is usually pulled over the plants in the early evening (about 5 p.m.) and removed at 8 a.m. in the morning. Black cloth can be pulled manually over frames or automatically.

Heat failure alarm - An alarm is installed on greenhouses to warn the greenhouse owner when the heating source fails. It is also activated when the greenhouse starts to become overheated. The alarm may be an auditory bell, a flashing light, or an automated telephone dialing warning system.

Summary

The greenhouse is designed to provide a nearly ideal environment for optimum growth and development of floriculture crops. The greenhouse environment may be controlled in various ways by manipulating ventilation (ridge and side ventilators, forced-air fans, and perforated convection tubes), heating (boilers, unit heaters, and infrared radiant heaters), and cooling (ventilation, forced-air fans, evaporative wet pads, and shading). Additional environmental controls include manipulation of the water supply, air circulation via turbulator fans and perforated convection tubes, and other equipment. Precise control of the greenhouse environment is necessary in order to produce quality plants.

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The interior layout varies from greenhouse to greenhouse. The type of plants and the marketing strategy will play an important part in determining the "best" interior layout. In order to produce the optimum number of plants in the amount of space available, it is important to understand interior layouts of greenhouses.

Wholesale vs. Retail Interior Greenhouse Layout

The wholesale operation emphasizes maximum usage of every available inch of growing space for crop production during all twelve months of the year. The overhead space is usually occupied by hanging baskets since growing a year-round crop of hanging baskets can increase greenhouse profits by one-third annually. Benches are spaced closer together (18 to 24 inches apart), and plants are spaced as closely as possible on them. The average bench height measures about 30 inches. However, bench height and width will vary widely between different wholesale greenhouse operations.

For maximum profit, there must never be empty production space in the wholesale greenhouse. The minute a crop is sold, another is set to grow in its place.

As a general rule, wholesale facilities are less convenient for workers than retail facilities. This is because the aisles are narrower and benches tend to be wider. Finally, the wholesale environment is not usually aesthetically beautiful since only the greenhouse owner and the work crew view the premises. Maximum crop production is all-important.

In contrast, a retail greenhouse is a welcome haven for customers; it must offer a convenient and pleasant shopping environment to stimulate sales.

Plants are best displayed when the customer can look down on them. This allows one to view the plants or flowers fully. For better display and to allow more sunlight below, there will be fewer hanging baskets overhead.

A peninsular benching system is the most widely used because it provides sufficient aisle space for the maximum number of customers in a retail greenhouse. Display benches should be about 24 to 30 inches above the ground. Hence, benches in retail operations tend to be lower than those found in wholesale greenhouses. This lets the customer browse and examine the plants easily.

Adequate spacing between plants on the benches should be provided, thus reducing plant damage and improving the customer's view. The walkways are wide and short so shoppers can easily pass each other. A wide center aisle facilitates the movement of shopping carts and wheelchairs.

Walkways should be finished in gravel or broom-finish concrete so that the customer can move through the greenhouse with little danger of slipping, being injured, or getting dirty.

The interior layout in a retail greenhouse must be designed to minimize injury to plant materials. It should be well-lit with artificial light, and plants and supplies should be within easy reach. The environment is convenient for greenhouse workers.

The retail greenhouse environment is designed to be aesthetically beautiful and appealing to shoppers. Pleasing the customer is all-important.

Importance of Raised Benches in the Greenhouse

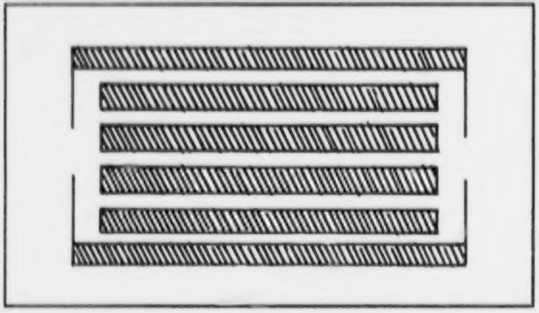
Raised benches act as growing platforms that help control each plant's environment. Benches improve air circulation around the plants, increase drainage away from container-grown plants, and isolate plants from insects and diseases. In addition, raising the benches off the ground reduces energy costs and enables workers to more efficiently care for the plants.

Benching Layout Designs

The placement of the benches will vary depending on the type of plants grown, as well as the purpose of the operation, wholesale or retail. The most common types of bench arrangements are lengthwise benching, crosswise benching, and peninsular benching. Some growers are making the best use of the growing area by using moveable benches. Fixed benches allow for approximately two-thirds of the area to be benches and one-third walkways. By using moveable benches, the grower increases the production area to eleven-twelfths of the total area.

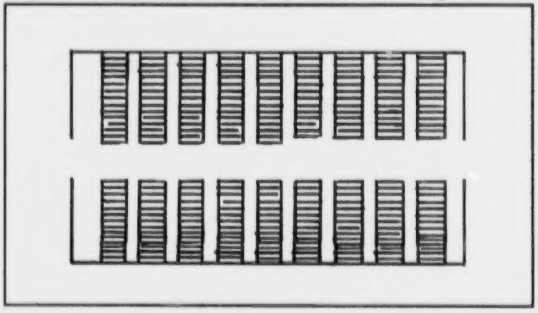
Lengthwise or longitudinal benching - Benches are traditionally installed lengthwise in greenhouses for cut flowers produced in ground beds. Ground beds are growing areas made of wood or concrete and located on the greenhouse floor. Lengthwise benching may also be used for production of potted plants. Worker efficiency is reduced because the greenhouse worker must walk around the entire bench to get to the other side. See Figure 6.1. However, lengthwise benching does provide support for heating lines and water lines without interfering with walkways.

Figure 6.1 - Lengthwise (Longitudinal) Benching



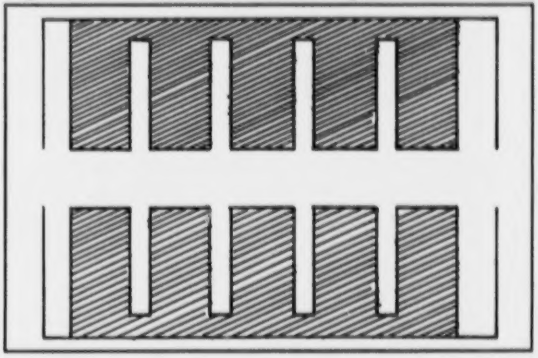
Crosswise or island benching - These benches are installed across the greenhouse with walkways down the center or sides of the greenhouse. See Figure 6.2. This type of bench placement is more efficient for the greenhouse worker and for the efficient use of space. Crosswise benching is used for container-grown plants, bedding plants, education, and research work.

Figure 6.2 - Crosswise (Island) Benching



Peninsular benching - This system is a modification of crosswise benching. A wide center walkway is provided with narrower aisles to provide access to each bench. See Figure 6.3. Container-grown plants and bedding plants are generally grown on peninsular benches. Bedding plants include young starter plants, most flowering annuals, or any other plant bought for planting in home garden beds. Peninsular benches provide more growing area than crosswise benches and are preferred for retail greenhouse operations.

Figure 6.3 - Peninsular Benching



Moveable benching - Moveable benches provide maximum efficiency of space. Benches are on wheels or rollers so that they can be easily moved. All of the growing area is occupied except for the aisle in which the greenhouse worker is working. Container crops that require less cultural care such as respacing, disbudding, and pinching are ideal for moveable benches.

Bench and Walkway Dimensions

The height of raised greenhouse benches is usually 24 to 30 inches. The width of benches will vary. A width of five to six feet is considered maximum for container-grown plants. Cut flower benches are generally narrower at three to four feet wide. Moveable benches can be up to six and one-half feet wide.

Walkways should be at least 18 inches wide for cut flower benches. For container-grown plants, the side aisles should be at least 24 inches wide. The center walkways should be 48 inches wide to allow for the movement of wheelbarrows and carts.

Greenhouse Bench Construction Materials

Raised benches can be made from wood, concrete, expanded metal, wire mesh, or plastic, while ground beds can be constructed from wood or concrete. Transite, a mixture of concrete and asbestos, can be found in some older greenhouses, but is no longer available for construction. Table 6.1 summarizes benching materials.

Wood - Wood is a popular choice for raised and ground benches. Although redwood is the second most expensive construction material, most other

Table 6.1 - Advantages and Disadvantages of Benching Materials

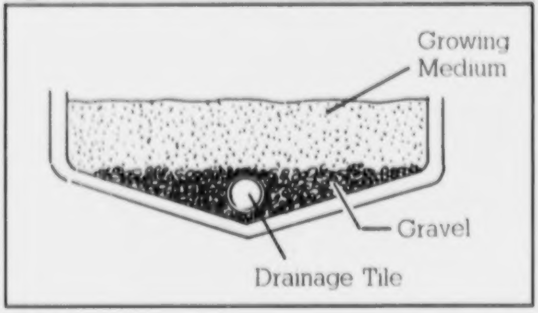
MATERIAL	ADVANTAGES	DISADVANTAGES
Wood	-Relatively low cost except redwood -Good air circulation -Lightweight -Easily adapted to moveable benches -Readily available	-Redwood is expensive. -Wood has a short life. -All wood except redwood, cedar, and cyprus must be treated with a wood preservative such as: copper naphthanate and zinc naphthanate. -Wood decays and absorbs water.
Concrete	-Stands up to steam sterilization -Extremely durable	-Expensive -Cannot be moved
Expanded Metal Fabric	-Prefabricated panels in various sizes -Maximum air circulation -No maintenance -Can be adapted to a moveable bench	-Very expensive -Can have rough edges if not finished or covered
Wire Mesh	-Maximum air circulation -Lightweight, easily moved -Inexpensive	-Rusts -Easily damaged -Sags with weight
Plastic	-Lightweight, easily moved -Durable -Does not absorb water -Can be adapted to a moveable bench -Easy to clean	-Available in only two sizes: 2'x8' and 3'x8' -Expensive

woods are relatively low in cost. Because they are lightweight, wood benches are easily adapted to moveable benches.Wood is readily available and easy to work with during construction. However, wood absorbs water and tends to have a short life unless treated.

Redwood, cyprus, and cedar are the preferred types of wood for bench construction, because they contain naturally occurring preservatives that resist decay. These woods do not need to be treated with a wood preservative. Any other wood used in a greenhouse should be treated with a preservative that is safe for plants. Chrome copper arsenate (CCA), copper naphthanate, latex paint, and zinc naphthanate are four recommended wood preservatives to enhance longevity of the wood. Do not use preservatives containing creosote or pentachlorophenol; they emit fumes that are toxic to plants. Since the natural preservative in redwood is corrosive to iron and steel, fasteners (i.e., nails, screws, and bolts) used in redwood should be aluminum, brass, or galvanized zinc. In addition, redwood lath in woven wire, similar to snow fencing, makes an excellent benching material.

Concrete - Concrete can be used in either ground beds or raised benches for the production of cut flowers. Concrete is considered the best material for ground benches (See Figure 6.5.) because it is the most durable. However, very few new greenhouses will use concrete as a benching material because the cost is so high and because it cannot be moved. Concrete costs tie with the second and third most expensive construction materials (i.e., redwood and plastic). Actual costs will vary, depending upon who pours and installs the concrete. In addition, concrete withstands steam sterilization of the growing media. Benches

Figure 6.5 - V-Bottom Concrete Ground Bench

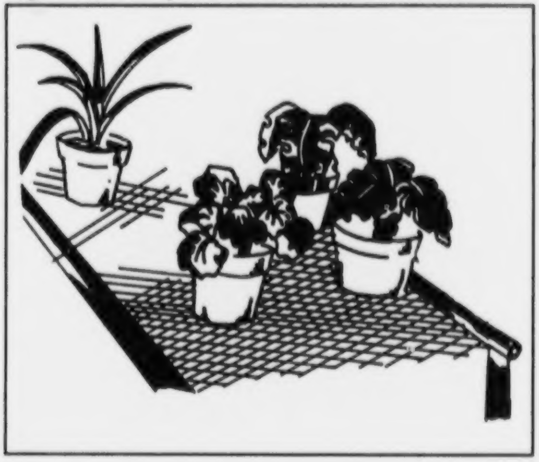


made of concrete are not moveable.

Construction of raised concrete benches requires special steel forms that are available on a rental basis. Very few, if any, new greenhouses are building raised concrete benches.

Expanded metal fabric - Expanded metal fabric makes an excellent surface for container-grown plants on raised beds. See Figure 6.6. The material is manufactured from 13-gauge carbon steel that is hot-dip galvanized. It is available in prefabricated panels of varying sizes. The expanded metal bench fabric can be supported on pipe, wood, or concrete blocks. This material can be used for the tops of moveable benches. It offers maximum air circulation for plants and requires no maintenance. Eventually the metal fabric will rust. The rough edges of the fabric must be covered to prevent injury to individuals or clothing. Expanded metal fabric is the most expensive construction material.

Figure 6.6 - Expanded Metal Fabric Bench



Wire mesh - Galvanized wire mesh is used for container-grown plants on raised benches. Wire mesh is similar in construction to expanded metal fabric except the wires are thinner and spaced closer together. Being somewhat flexible, the wire mesh must be nailed or stapled to a frame made of two-inch by four-inch boards or metal. The wire mesh comes in widths of 36, 48, and 72 inches and is less expensive than expanded metal. Concrete blocks or wood is generally used for the legs of the bench that support the frame to which the wire mesh has been attached. Wire mesh allows maximum air circulation, and because it is lightweight, it is adaptable to moveable benches. However, it rusts and is easily damaged. A wire mesh bench may sag from the weight of containers.

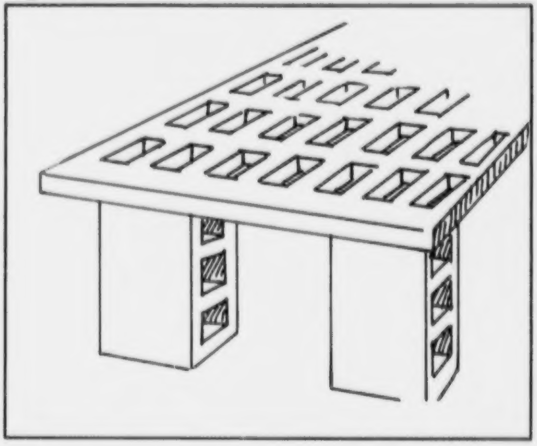
Plastic - This raised bench surface is used for container-grown plants. See Figure 6.7. Molded plastic is a new benching material that comes only in two sizes: two feet by eight feet and three feet by eight feet. It is lightweight, so it can be adapted to moveable benches. The panels are supported on concrete blocks. Plastic is durable, easy to clean, and does not absorb water. Plastic is the third most expensive construction material.

Walkway Materials

The most common types of walkway materials used in greenhouses are gravel, concrete, and asphalt.

Gravel - Gravel is the least expensive walkway material used in a greenhouse. No other drainage needs to be provided with gravel. Gravel has a rough surface, making the use of carts and wheelbarrows difficult.

Figure 6.7 - Plastic Bench



Concrete - Concrete is the most common and most expensive form of walkway material for greenhouses. Concrete may be used only for the walkways or for the entire floor. Standard concrete may have either a rough or a broom finish. Drains must be used on standard concrete to eliminate excessive water. A porous concrete can be used for flooring in greenhouses. It allows water to pass through it and is safe to walk on with very little threat of slipping. Concrete provides a smooth surface, making the use of carts and wheelbarrows easy.

Asphalt - Asphalt provides a smooth surface and is less expensive than concrete. Asphalt is generally re-sealed once a year. Its surface becomes slick when wet. Asphalt provides a good surface for the use of carts and wheelbarrows.

Summary

The wholesale operation emphasizes maximum usage of every available inch of greenhouse growing space for year-around crop production. In contrast, the retail greenhouse stresses aesthetic beauty of plant displays and a pleasant, convenient environment for shoppers. The purpose of the facility, along with the crop(s) grown, will determine all aspects of the greenhouse interior design (e.g., bench and aisle layout, dimensions, and choice of construction materials).

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Energy conservation in greenhouse operations is a matter of economic importance. In order to keep production costs down, it is necessary to understand the different techniques and procedures that can be used to conserve energy in greenhouses.

Energy Conservation in the Greenhouse

Energy conservation is important because greenhouses use massive amounts of fuel, and there is a limited supply of fossil fuels such as gas, oil, and coal. This limited supply causes the price of fuel to rise continually. The increasing costs of fuel needed to heat a greenhouse result in higher production costs. Currently, heating is the second highest overhead cost in the greenhouse. (Labor is the highest.)

The Effect of Orientation, Location, and Climate on Greenhouse Energy Usage

Orientation of a greenhouse to obtain maximum light all year is an important consideration. Orient the long axis of the greenhouse north-south when located south of the Mason-Dixon line (38th parallel), and east-west when north of the line. The Mason-Dixon line is located on the southern border of Pennsylvania.

Greenhouses should be built in protected areas, especially in areas of low winter temperatures. A fifteen mile per hour wind can double the amount of heat lost by a greenhouse. If building a greenhouse, the smallest cross section should face the prevailing winds. The wind velocity affects not only the loss of heat in the winter but also the cooling efficiency in the summer.

Before building a greenhouse, the existing climatic conditions should be reviewed by looking at weather bureau records. Weather bureau records can tell you the average annual temperature, percentage of annual sunlight, wind velocity and direction, and the amount of precipitation.

Using Windbreaks to Conserve Energy

Windbreaks can provide a protected area for greenhouses and result in a five to ten percent savings in fuel. Windbreaks should never cast a shadow on the greenhouse. Windbreaks on the east, west, or south side should be located a distance of two and one-half times the height of the windbreak away from the greenhouse. Trees 30 feet tall will affect the wind speed 100 yards upwind and 300 yards downwind. Windbreaks should be 60 percent porous to decrease wind velocity and reduce energy costs. Evergreen trees are often planted as windbreaks. Materials such as snow fencing can be used to build a temporary windbreak. For a greenhouse of average height (11-14 feet), a windbreak 10-12 feet high located 40-60 feet upwind from the greenhouse is ideal.

Greenhouse Modifications and Procedures to Conserve Energy

There are many procedures for modifying an existing greenhouse to conserve energy. These same modifications and procedures are often incorporated into the construction design and operations manual of a new greenhouse.

Some energy conserving modifications and procedures are as follows: a double layer of polyethylene, a double layer of polyethylene over the existing cover of glass or fiberglass, laminated glazing material, lap sealing existing glass, thermal blankets, insulated sidewalls and foundations, completely insulated north-facing walls, proper maintenance of the greenhouse covering and heating equipment, conversion to high effeciency radiant heaters, and the use of air circulation fans.

Double layer polyethylene by itself - A double layer of polyethylene with an inflated airspace of 5/8 inch to four inches between the layers retains 33 to 40 percent more heat than glass. An insulating air space is created between the two layers of polyethylene by using a four-inch squirrel-cage blower for inflation. The blower runs constantly. The film will need to be replaced every two to three years. The double covering does reduce light intensity by as much as 18 percent and thus can adversely affect the growth of plants.

Single or double layer of polyethylene over existing cover of glass or fiberglass - To safeguard against air infiltration and to provide insulation, greenhouses can be sealed by placing a single or double layer of polyethylene over glass or fiberglass and fastening the edges with aluminum poly-lock strips. A fuel savings of up to 57 percent can result by using a double layer of polyethylene over an existing cover. Refer to discussion of double-layered polyethylene for additional information.

Laminated glazing material - A 40 to 50 percent fuel savings can be achieved by replacing the existing cover with a double-skinned glazing material such as acrylic or polycarbonate. The cost of rigid glazing material is expensive.

Lap sealing - Lap sealing a glass greenhouse is a one-time process that will last the life of the greenhouse. A clear silicon sealant is injected where the panes of glass overlap one another. The process is similar to caulking. Fuel savings of five to 40 percent, depending upon the original tightness of the glass, may result from lap sealing.

Thermal blankets - A curtain of polyethylene, Mylar®, or aluminized fabric is drawn over the growing area and around the inside perimeter of the greenhouse each night. The thermal blankets are retracted each morning. Thermal blankets reduce the amount of space heated, reflect radiant heat toward the plants, and reduce conductive heat loss by forming an insulated barrier above the plants. Thermal blankets can reduce fuel consumption by 40 to 65 percent.

If a greenhouse has an overhead heating system, modification will have to be made to distribute the heat under the thermal blanket. If water pipes are above the blanket, they will need to be protected from freezing. On nights when snow or ice is expected, the thermal blanket should not be pulled. Heat will be needed in the gables to prevent a build-up of snow or ice on the roof, which may cause the roof to collapse. Thermal blankets can also be used as blackcloth for photoperiod control, thus controlling the timing of flowering.

Insulated sidewalls and foundations - A three to six percent savings in fuel can result when the sidewalls and foundation are insulated. Rigid white Styrofoam® sheeting, white Microfoam®, a bubble-pack type material, or blueboard polystyrene can be used to insulate a greenhouse. The Styrofoam® sheeting is lightweight, inexpensive, and reflects light. Microfoam® is a closed-cell polyethylene foam. This inexpensive insulation reflects light well, but deteriorates when exposed to ultraviolet rays. Microfoam® is flexible and easily cut for custom shaping around vents. The bubble-pack type material is made of two layers of polyethylene bonded together with air bubbles trapped in between. This material is easily applied to glass by surface tension, clipping, or taping. It is transparent and reduces light transmission by only eight percent. Blueboard polystyrene is used to insulate sidewalls' exteriors below the soil line.

Completely insulated north-facing end wall - The north-facing end wall of the greenhouse, especially in cold climates, may be completely covered with inexpensive white Styrofoam® sheeting insulation or white Microfoam® insulation. Both will reflect a large amount of light back into the greenhouse growing area. Such a solid wall offers excellent protection from the harsh north winds of winter.

Proper maintenance of the greenhouse covering and heating equipment - A heat savings ranging from three to ten percent can be achieved by replacing broken panes of glass, sealing cracks, and covering unused vents. Heating equipment should be cleaned, inspected, and adjusted annually for maximum fuel efficiency. When conserving energy, it is important to remember that a unit heater burning fuel must be provided with adequate fresh air intake to insure complete burning of fossil fuel.

Conversion to high efficiency radiant heaters - Converting to a radiant heating system can result in a fuel savings of 30 percent or more. If the ridge of the greenhouse is more than 12 feet high, radiant heating can be combined with the use of thermal blankets. In this instance, the thermal blanket would run from eave to ridge instead of eave to eave.

Air circulation fans - The use of air circulation fans will return the warm upper air from the attic down toward the plants and save heating expenses.

Cultural Procedures Used to Conserve Energy

Four cultural procedures (i.e., practices used when growing greenhouse crops) will conserve energy. They are lower night temperatures, split-night temperatures, bottom heat, and improved space utilization.

Lower night temperatures - Reducing the night temperature will result in fuel savings. Certain greenhouse crops can be grown at cooler night temperatures. If the night temperature is reduced, the production time usually increases. The use of warm water will promote the growth of warm season crops in a cool greenhouse. Select plant species that require cooler night temperatures during the winter months such as cineraria, calceolaria, and primula.

Split-night temperatures - Researchers have found that using split-night temperatures resulted in a fuel savings of six percent. The quality of the crops and the production time was not affected by the split night temperatures. The greenhouse temperature is kept at an optimum night temperature until 11:00 p.m., when it is allowed to drop to a much cooler temperature (approximately

45°F) until dawn. At dawn the temperatures are increased and the plants are watered with warm water.

Bottom heat - If the plant's roots are kept warm, they can tolerate much cooler air temperatures. By heating the soil to 65° to 70°F and reducing the air temperature to about 55°F, fuel costs can be reduced. Unfortunately, this method would require major renovation of most heating systems in today's greenhouses.

Improved space utilization - Making the best use of greenhouse space helps to conserve energy. There are three ways to use greenhouse space more efficiently: progressive spacing, moveable benches, and multiple-shelf benches.

Progressive spacing involves increasing the space between the pots only when more room and light are required. Progressive spacing can result in 50 percent more bench space. The use of a moveable benching system will increase the growing space by 25 percent. Multiple-shelf benches provide more production space in a given area than a flat bench. A pyramid-type or A-frame bench allows for the production of low light-requiring plants on the bottom shelves and higher light-requiring plants on the top shelves.

Summary

Since a greenhouse functions like a giant radiator, the amount of fuel usage is significant. In fact, fuel cost is the second highest overhead expense in greenhouse operations. Therefore, greenhouse operators must do everything possible to conserve energy. First, proper greenhouse orientation and windbreaks are important in the physical environment outside the greenhouse. Structural modifications and procedures, as well as special cultural or crop-growing practices, should be used inside the greenhouse. By conserving energy, profits will be maximized.

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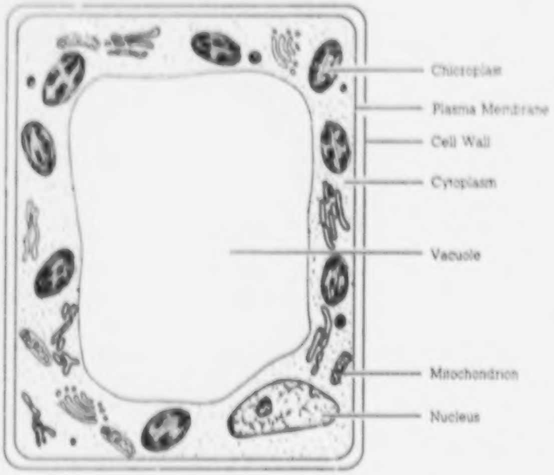
Man depends on plants for survival. To understand how plants grow and to provide optimum conditions favorable for plant growth, it is essential to understand plant parts, structures, and functions.

Functions of Plant Cell Parts

A cell is the smallest unit of all living organisms. Cells are the building blocks that are responsible for carrying out the process called life. Cells come in many types and forms. All plant cells have nearly the same interior structure. See Figure 8.1.

Figure 8.1 - Plant Cell Structure



The cell wall is made up of three parts: the primary wall, the middle lamella, and the secondary wall. The primary wall is the first part of the cell wall to develop. The middle lamella is the layer between the walls of two adjacent cells. The secondary wall is formed inside the primary wall and becomes the woody part of the plant as the plant develops.

Composed of molecules of proteins, carbohydrates, and phospholipids (phosphorus and fat), the plasma membrane is located just inside the plant cell wall. This membrane is differentially or selectively permeable and controls the movement of substances by osmosis in and out of the cell.

Acting as the "gatekeeper," the plasma membrane will let some substances (e.g., water) enter the cell easily, while other substances are allowed to enter slowly or are blocked from entering. The second function of the plasma membrane is to sense the outside environment and relay this information to the nucleus of the cell. Thus, based on this information, the cell will respond appropriately to environmental conditions.

Cytoplasm is the liquid contained within the cell wall. The cytoplasm is a complex substance containing the organelles and is responsible for carrying out most of the life processes. Another name for cytoplasm is protoplasm.

The nucleus is the organelle (membrane-bound sack), which is the control center of the cell. The nucleus contains the genetic material, including the chromosomes. One of the functions of the nucleus is to determine the physiological characteristics of the plant and its appearance. Another function is to transmit the hereditary characteristics to the offspring.

The cytoplasm also contains a number of small dense organelles known as mitochondria. The functions of the mitochondria include controlling many of the chemical reactions in the cell and providing a site for respiration.

Plastids are small organelles located within the cytoplasm. The plastids contain the green, red, orange, and yellow pigments found in plants. The plastids that contain the green pigment, or chlorophyll, are called chloro-plasts. Chloroplasts are needed to carry on the photosynthesis process. The yellow, red, and orange pigments contained in plastids are called chromoplasts. Chromoplasts give color to petals and bracts.

Vacuoles are large, fluid-filled organelles contained in the cytoplasm. They store water, dissolved minerals, and other materials. As a plant approaches maturity, the vacuoles become larger and join together to form one large central vacuole which is the primary storage area in the cell.

Functions of the Plant Parts

The four basic parts of a plant are roots, stems, leaves, and flowers. The roots anchor the plant, absorb water and minerals and translocate them to the stem, and store food. The functions of the stem are to translocate water, minerals, and food to the leaves, to support the leaves and display them to light, and to store food (in some plants). The functions of the leaves are to manufacture food for the plant through photosynthesis, to facilitate the exchange of gases with the atmosphere in the process of respiration and photosynthesis, and to store food in some plants. The flower has two functions. It contains organs specialized for sexual reproduction and produces seeds and fruit.

Functions of Specialized Plant Tissues

Plant tissues are divided into two groups: meristem tissues and permanent tissues. Meristem tissues are cells that actively divide to form new growth. Permanent tissues (e.g., epidermis, xylem, and phloem) are composed of mature cells that do not actively divide.

Meristem tissues - There are three types of meristem tissues: apical meristems, cambial meristems, and intercalary zone meristems. Apical meristem tissues are located at the tips of the roots and stems. When the apical meristem tissues divide, there is an increase in the length of the plant. Cambium meristems are located in the stems; they increase the plant's size by increasing its width. Cambium meristem tissues that are dormant can change back to actively dividing meristem cells when a plant is propagated or is wounded. Intercalary zone meristems are located just above the nodes in monocot plants; they increase stem height.

Permanent tissues - There are several types of permanent tissues. Included among these are the epidermis, xylem, and phloem tissues. Epidermis tissues are found on the outside covering of the plant. The epidermis tissues protect and support the inner cells of the plant. The xylem and phloem tissues make up the vascular system of plants. They form a continuous path from the roots through the stems to the leaves. The function of the xylem tissues is to translocate water and dissolved minerals upward. Phloem tissues translocate food manufactured through photosynthesis from the leaves to the stems and roots for storage, to meristem tissues for growth, and to all plant cells for immediate use.

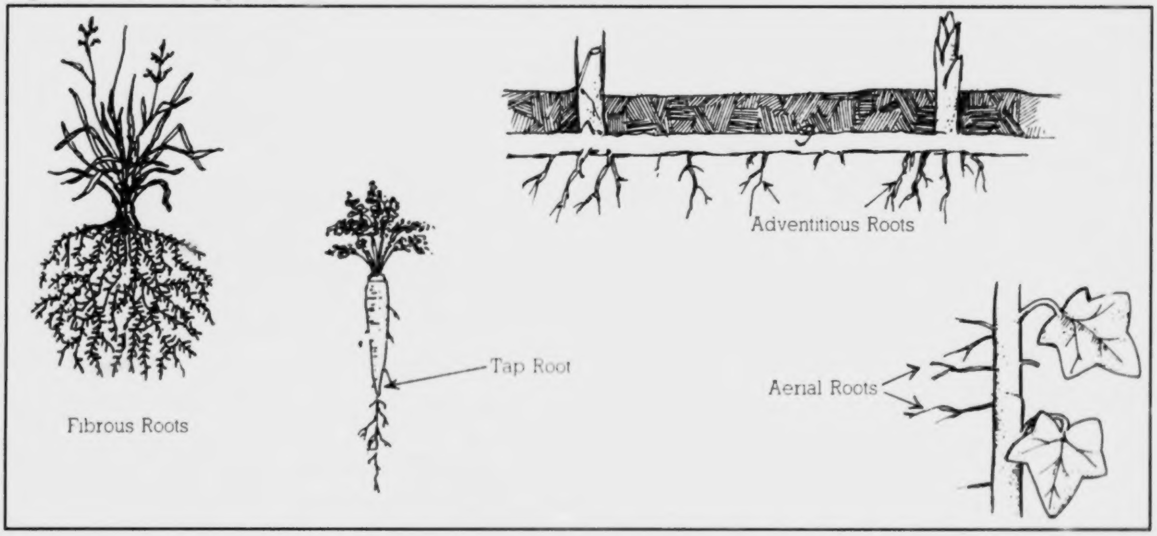
Types and Functions of Roots

There are five types of roots: tap, fibrous, aerial, aquatic, and adventitious. Figure 8.2 illustrates several root types.

Tap root - A tap root is a continuation of the primary root. Plants having tap roots are well-anchored and can penetrate to greater depths to obtain water even during dry periods. A tap root is generally thick and fleshy and serves as a storage area for food manufactured by photosynthesis. A carrot is an example of a plant with a tap root.

Fibrous roots - In plants having fibrous roots, the primary root is surpassed by the growth of finely branched secondary roots. Plants with a fibrous root system are usually shallow-rooted and cover

Figure 8.2 - Root Types



a large area of soil. Fibrous roots are more effective in absorbing water and minerals because of their greater surface area. Plants having fibrous roots have extensive root systems which help prevent soil erosion. Many grasses have a fibrous root system.

Aerial roots - There are two types of aerial roots: clinging or anchoring air roots and absorptive air roots. English ivy and Virginia creeper are two plants that have clinging air roots. Clinging air roots are very short roots that grow out horizontally from the stems and fasten the plant to a support. Absorptive air roots have thick outer coverings of dead tissue that absorb and store water. Orchids have absorptive air roots.

Aquatic roots - Plants having aquatic roots have the ability to absorb oxygen and nutrients from water. Water lilies have aquatic roots.

Adventitious roots - Roots that develop in places other than nodes are called adventitious roots. Adventitious roots can form on a cutting or on a rhizome.

Hair Roots

Hair roots or root hairs are tiny, one-celled, hair-like extensions of the epidermal cells located near the tips of the root where vascular tissues have formed. The hair roots greatly increase the surface area of the roots. Most of the water and nutrients used by a plant are absorbed by the hair roots.

Hair roots grow very quickly, but are short-lived. When plants are transplanted, many hair roots are damaged, reducing the amount of water a plant can absorb. To help the plant overcome transplanting shock, the plant should be often misted, shaded, and trimmed of excess leaves to reduce the surface area where transpiration occurs.

The Principal Functions of Stems

Stems serve many functions for the plant, such as supporting branches, leaves, flowers, seeds, and fruit. They also give the plant height and expose it to sunlight. In special cases, stems may be a site for photosynthesis. Some store food. In addition, stems contain vascular tissues that transport water, dissolved minerals, and manufactured food.

Specialized Stems

There are seven types of specialized stems: corms, bulbs, tubers, crowns, spurs, rhizomes, and stolons.

Corm - A corm is a solid, fleshy, scale-covered enlargement. It is usually an underground stem. Gladiolus and crocus are two types of plants that have corms.

Bulb - A bulb is an underground stem that consists of layers of fleshy scales that overlap each other, like an onion. Other plants that have bulbs are tulips, daffodils, and lilies.

Tuber - A tuber is a short, thick, underground stem which serves primarily as a food storage area. Potatoes and caladiums are examples of plants with tubers.

Crown - A crown is a group of closely grouped stems or plantlets just above and below the ground line. Examples of plants having crowns are African violets and ferns.

Rhizome - A rhizome is an underground stem that produces roots on the lower surface and extends leaves and flowering shoots above the ground. Iris, lily-of-the-valley, and many grasses are examples of plants that have rhizomes.

Stolon - A stem that grows horizontally above the soil surface is called a stolon. Some plants having stolons are strawberries and airplane plants.

Principal Leaf Tissues

There are three principal tissues in the leaf: epidermis, mesophyll tissues, and veins or vascular bundles. The primary function of the leaf is to manufacture food for the plant through photosynthesis.

Epidermis - The upper and lower surface of the leaf has an epidermis. Three parts are involved: cuticle, stomata, and guard cells.

The cuticle is made of a waxy substance that forms a waterproof layer covering the epidermis. The cuticle helps keep water inside the plant. The epidermis is a layer of protective cells containing many stomata and guard cells. The stomata (plural form of stomate) are openings in the epidermis that allow for the exchange of water and gases such as carbon dioxide and oxygen. Most stomata are found on the underside of leaves.

Guard cells are specialized cells located on each side of a stomate. Two guard cells control the opening and closing of each stomate.

Mesophyll tissues - There are two layers of mesophyll tissues: palisade and spongy mesophyll. The palisade mesophyll tissues are elongated cells located under the upper epidermis. Since they contain many chloroplasts, most of the photosynthesis process occurs in the palisade mesophyll layer. The spongy mesophyll tissues are located between the palisade mesophyll and the lower epidermis. They are a mass of irregularly shaped cells that contain chloroplasts interspersed with numerous air spaces. Photosynthesis and the exchange of gases with the palisade cells occur in the spongy mesophyll.

Veins or vascular bundles - The veins or vascular bundles are made up of two types of tissues: the phloem and xylem. The phloem tissues translocate food from the photosynthesizing cells to the rest of the plant. The xylem tissues translocate water and dissolved minerals to the photosynthesizing cells. The vascular bundles are located in the spongy mesophyll layer of the leaf.

Modified Leaves

There are five types of modified leaves: scales, bracts, tendrils, thorns, and sacs. The functions of the modified leaves vary.

Scales - Scales are hard, plate-like structures that protect the bud of woody plants during the winter. A juniper is an example of a plant having scales.

Bracts - There are two types of bracts: leafy and fleshy. The function of brightly colored leafy bracts near the flowers is to attract pollinating insects. Poinsettias and dogwoods are two types of plants that have leafy bracts. The function of fleshy bracts is to store nourishment for the developing seeds. A globe artichoke is an example of a plant having fleshy bracts.

Tendrils - Slender, thread-like, modified leaves that twine are called tendrils. The function of tendrils is to support and anchor the plant. Grapevine and morning glory are two types of plants that have tendrils.

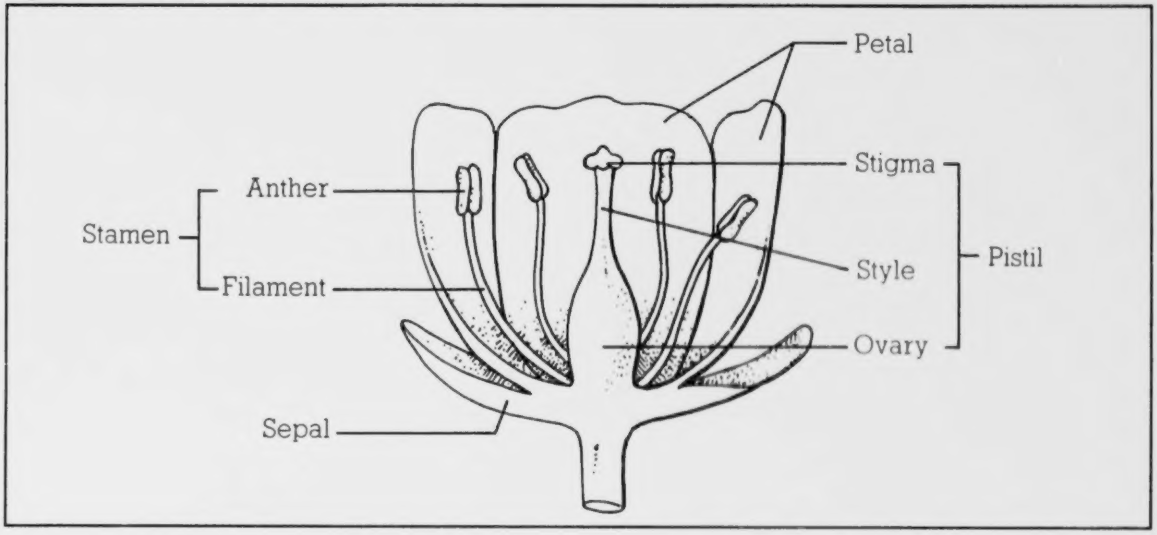
Thorns - Thorns are very short, hard, modified leaves with a sharp point. Thorns protect the plant from grazing animals. Roses have thorns.

Sacs - A pouch-like modified leaf is called a sac. The functions of sacs are to hold water and to catch insects. The carnivorous-type plants such as sundews and Venus fly-traps have sacs.

Functions of Flower Parts

There are four parts of a flower: sepal, petal, stamen, and pistil. Sepals and petals are the vegetative part of the flower. The stamens and pistils are the reproductive parts of the flower. Figure 8.3 illustrates the four parts of the flower, as well as the parts that make up the stamen and pistil.

Figure 8.3 - Flower Parts



Sepals - When the flower bud is closed, the outer, scale-like covering is formed by the sepals. All of the sepals together are called the calyx. The function of the sepals is to protect the petals, stamens, and pistils when the flower is in the bud stage.

Petals - The petals are usually brightly colored to attract pollinators (usually insects). All of the petals together are called the corolla. The petals protect the stamens and pistils in the bud stage.

Stamens - The stamen is the male reproductive part of the flower. Each stamen consists of two parts: the anther and the filament. The anther produces pollen grains, and the filament supports the anther.

Pistil - The pistil is the female reproductive part of the flower. The pistil consists of the ovary, stigma, and style. The ovary is the enlarged portion at the base of the pistil. The function of the ovary is to produce ovules. Ovules that are fertilized become seeds. The stigma receives and holds the pollen grains, and the style connects the stigma with the ovary. Pollen grains travel through the style to reach the ovary. The style supports the stigma so that it may be pollinated.

Complete and Incomplete Flowers

A complete flower has all four of the main parts of a flower: sepals, petals, stamens, and pistils. An incomplete flower is missing one or more of the main parts of a flower. An apetalous flower is an incomplete flower that has no petals. A staminate flower is an incomplete flower with a functional stamen but no pistils. A pistillate flower is an incomplete flower with a functional pistil but no stamen. Some plants, such as members of the grass family, lack sepals; therefore, they are incomplete.

Perfect and Imperfect Flowers

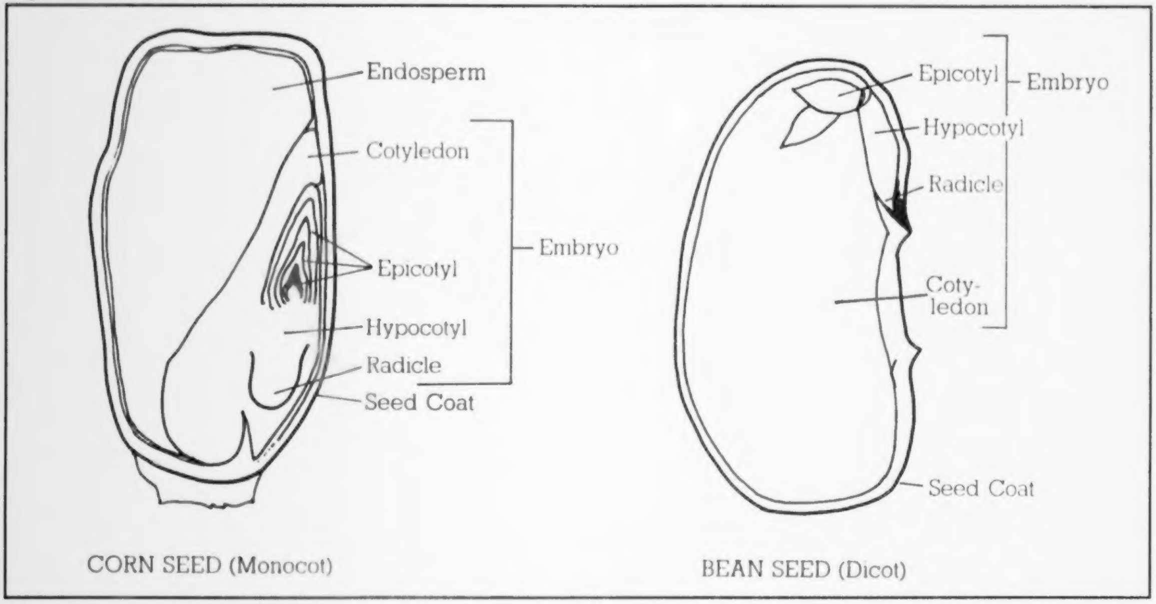
A perfect flower contains both male and female flower parts: stamens and pistils. It may or may not have sepals and petals. Perfect flowers are often self-pollinating. Lilies are an example of a perfect flower. A perfect flower that contains all four main parts is complete.

Imperfect flowers contain male or female parts; therefore, they are always incomplete. A cucumber, for example, produces male flowers and female flowers. Two types of imperfect flowers are staminate and pistillate. Staminate flowers contain only the male part, the stamen. Pistillate flowers contain only the female part, the pistil. Imperfect flowers often cross-pollinate.

Functions of the Seed Parts

A seed is a very young or embryonic plant in a dormant or resting stage with a supply of food and a seed coat. Figure 8.4 illustrates the longitudinal veiws of dicot and monocot seeds. The seed has

Figure 8.4 - Seed Parts



CORN SEED (Monocot)

BEAN SEED (Dicot)

three basic parts: the seed coat, the embryo, and the endosperm.

Seed coat - The seed coat is the hard exterior surface of the seed. The seed coat serves two functions: it prevents the seed from drying out and it protects the embryo from mechanical injury.

Embryo - The embryo is a miniature plant contained within the seed coat. The embryo has four distinct parts: the epicotyl, the hypocotyl, the radicle, and the cotyledons.

The epicotyl (plumule or growth bud) will develop into the first shoot with a leaf or leaves that emerge from the seed upon germination. The epicotyl is located above the cotyledon(s).

The hypocotyl is the first true stem of the plant. As the hypocotyl lengthens, the cotyledons and epicotyl emerge from the seed during germination. The hypocotyl is located below the cotyledon(s).

The radicle (root tip) is located at the end of the hypocotyl. The radicle is the first root of the plant. As the seed germinates, the radicle is the first part of the embryo to emerge. The function of the radicle is to hold the developing plant in the soil and to absorb water and nutrients from the soil.

The cotyledon is the beginning of the seed leaves. Monocotyledonous plants (or monocots) have one cotyledon. Dicotyledonous plants (or dicots) have two cotyledons. The function of the monocot cotyledon is to protect the epicotyl. The dicot cotyledons not only protect the epicotyl, but also serve as a place to store food for the new plant.

Endosperm - The endosperm is found only in monocot seedlings. The function of the endosperm is to store food for the developing plant until it is able to produce its own food through photosynthesis.

Types of Flowering Plants

There are two types of flowering plants: monocots and dicots. Monocots are plants that produce one cotyledon. Monocotyledonous plants have leaves with parallel veins, vascular bundles scattered within the stems, and flowers that have parts in threes or multiples of three. Lilies, corn, and grasses are examples of plants that are monocots. Dicots are plants that produce two cotyledons. Dicots have leaves that have a branched network of veins, stems with vascular bundles in a ring pattern, and flower parts in fours or fives or multiples of four or five. Most flowering plants, vegetables, deciduous trees, and shrubs are dicotyledonous plants.

Summary

In order to understand growth, reproduction, and all the other processes occurring within the plant, it is important to understand basic plant cell structure, gross plant structure, and plant physiology (functions of the various parts).

Credits

Adams, U.D.; Leo Perkins. Greenhouse Management and Operation. College Station, TX: Vocational Instructional Services, Texas A&M University, 1975.

Boodley, James W. The Commercial Greenhouse. Albany, NY: Delmar Publishers Inc., 1981.

Hopkins, Betty T. Horticulture I - A Curriculum Manual. Santa Fe, NM: The Vocational-Technical Division of the New Mexico State Department of Education, 1975.

Laurie, Alex; D.C. Kiplinger; Kennard S. Nelson. Commercial Flower Forcing. 8th ed. New York, NY: McGraw-Hill, 1979.

Reily, H. Edward; Carroll L. Shry, Jr. Introductory Horticulture. Albany, NY: Delmar Publishers, Inc., 1988.

Swanson, John. "Plant Science Unit," Agricultural Science I Core Curriculum. University of Missouri-Columbia: Instructional Materials Laboratory.

There are basic processes which plants depend upon for growth. In order for plants to grow properly, it is important to understand how these processes affect optimum growth.

Basic Plant Processes

There are five basic processes involved with plant growth: photosynthesis, cellular respiration, water absorption, translocation, and transpiration.

Photosynthesis

Photosynthesis is the process by which green, living plants convert carbon dioxide and water in the presence of light into simple sugar. The formula is illustrated in Figure 9.1.

Figure 9.1 - Photosynthesis Formula

$$\underset{\text{(carbon dioxide)}}{6\ CO_2} + \underset{\text{(water)}}{6\ H_2O} \; \frac{\text{chlorophyll}}{\text{light energy}} > \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6\ O_2}$$

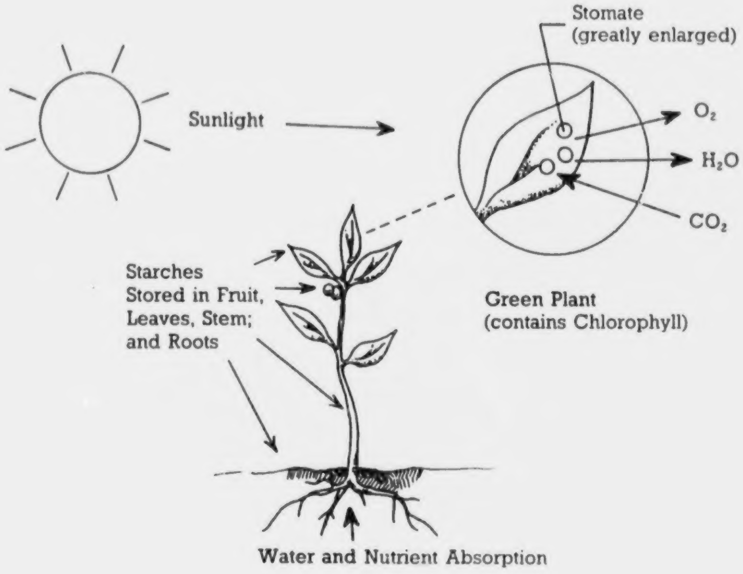
Simplified Steps in the Photosynthesis Process

Carbon dioxide gas enters the plant through stomata, primarily located on leaves. Water is absorbed by the hair roots and then enters the leaves by the xylem tissues. Light strikes the chlorophyll, which is present in the chloroplasts in the mesophyll cells of the leaf and stem. Light energy is absorbed, enabling a chemical reaction to take place between carbon dioxide and the hydrogen in water. Glucose, a simple sugar, is produced and transported by the phloem tissues to other parts of the plant. Oxygen is released as a by-product through stomata. Water is always released when the stomata open. See Figure 9.2.

Cellular Respiration

Cellular respiration is the controlled breaking down of glucose, releasing energy for plant growth, absorption, translocation, and many other metabolic processes or chemical reactions occurring within the cell. Glucose molecules are combined

Figure 9.2 - Photosynthesis Process



and stored in the form of a complex starch molecule in vacuoles within the cells. Nearly all respiration occurs in the presence of O_2 (aerobic respiration). However, some cellular respiration may occur for a short time without oxygen (anaerobic respiration). The formula for aerobic respiration is illustrated in Figure 9.3.

Figure 9.3 - Cellular Respiration Formula

$C_6H_{12}O_6$	+	$6\ O_2$	----->	$6\ CO_2$	+	$6\ H_2O$	+	Energy
(glucose)		(oxygen)		(carbon dioxide)		(water)		

Cellular Respiration: A Basic Life Process

The primary importance of respiration is that it enables the plant cell to release energy which is then used in many energy-requiring chemical reactions within the cell. In addition, respiration releases CO_2 and H_2O into the atmosphere. Cellular respiration is a continuous process occurring twenty-four hours a day, for as long as the organism lives.

Water Absorption by Plants

Absorption is the process by which water containing dissolved minerals enters the plant's hair roots. The movement of water and dissolved minerals from the soil into plant root cells is by the process of osmosis. Osmosis is a special type of diffusion; the diffusion process is the movement of molecules from a place of higher concentration to a place of lower concentration. Osmosis is the diffusion of water through a differentially permeable membrane. For example, the plasma membrane surrounding the living plant cell will allow some molecules and materials--depending on their chemical properties and size--to pass through easily and quickly enter the cell, while other materials are allowed to pass through very slowly, and still other materials are blocked from entering.

Translocation

Translocation is the movement of water soluble organic materials and nutrients within the plant. The vascular system, consisting of xylem and phloem tissue, is the means by which translocation occurs. Water translocation is primarily upward from the roots through the xylem, while food (glucose) translocation through the phloem is from the leaves to the rest of the plant, including the root system.

The Transpiration Process

Transpiration is the loss of water by evaporation primarily from the leaf surface, although it also occurs from the stem and petals. Transpiration occurs inadvertently when the plant's stomata open to take in carbon dioxide, a raw material needed for photosynthesis. Transpiration is greatly influenced by environmental factors such as light, temperature, relative humidity, and wind.

Summary

Five processes affect plant quality and longevity. Through the process of photosynthesis, a green plant manufactures its own food (simple sugar or glucose). The process of cellular respiration burns

Figure 9.4 - Comparison of Photosynthesis and Cellular Respiration

	PHOTOSYNTHESIS	CELLULAR RESPIRATION
Energy relationships - stored or released	Stored	Released
Raw materials	CO_2 and H_2O	Glucose and O_2
Function	To convert sun energy into chemical energy	To release energy from glucose for cellular metabolism
End products	O_2 and glucose	CO_2, H_2O, and energy

this glucose to release energy needed in many energy-requiring chemical reactions within the cell. Water and dissolved mineral nutrients enter roots by the process of absorption. Translocation is the movement of water, dissolved minerals, glucose, and other organic compounds within the plant. Transpiration is the process of water loss from the plant, primarily through stomata located on leaves. Figure 9.4 compares photosynthesis and cellular respiration.

Credits

Adams, U.D.; Leo Perkins. Greenhouse Management and Operation. College Station, TX: Vocational Instructional Services, Texas A & M University, 1975.

Hopkins, Betty T. Horticulture I. A Curriculum Manual. Santa Fe, NM: Vocational Technical Division of the New Mexico State Department of Education, 1975.

Laurie, Alex; D.C. Kiplinger; Kennard S. Nelson. Commercial Flower Forcing. 8th ed. New York: McGraw-Hill, 1979.

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Environmental factors have a direct effect on plant growth. To produce quality plants, it is important to understand how the primary environmental factors influence plant growth through their effect on the basic plant processes. These environmental factors include light, temperature, water, gaseous components of air, and mineral nutrients.

Light Intensity and Its Measurement

Light intensity is the quantity of light or the brightness of light. Relatively high light intensity is needed by most greenhouse-grown plants to start and continue photosynthesis. A measure of the intensity or brightness of light is a footcandle (fc). One footcandle is the amount of light striking a surface at a distance of one foot from a standard wax candle.

Effects of Light Intensity on Plant Growth

Plants grown in a greenhouse are grouped in three light intensity groups: high, medium, and low light intensity. Low light intensity plants should receive between 500 and 1,250 fc. Medium light intensity plants prefer 1,250 to 2,500 fc. High light intensity plants need more than 2,500 fc for growth and flowering. The majority of plant species require at least 2,000 fc for optimum growth.

Usually the natural light intensity is excessive in the summer and deficient in the winter. This depends on greenhouse location and condition, crops grown, and stage of growth. Light intensity can be reduced from mid-spring to early fall by using a shading compound or shade fabric. Supplemental lighting can be used if natural light conditions are low intensity. High intensity discharge (HID) lamps help plant growth. Properly spaced, these lamps provide 600 to 1,000 fc at an economical cost.

Plants receiving deficient light intensity demonstrate the following growth and development characteristics: longer internodes, reduced pigment formation, weak stems, less leaf area, and no flowering. In addition, photosynthesis is reduced as light intensity is reduced.

Plants which receive adequate light intensity demonstrate the following growth and development characteristics: increased height, thicker stems, greater leaf area, shorter internodes, more roots, earlier flowering, more flowers, larger flowers, and increased pigment formation. Photosynthesis increases to an optimum level.

If plants receive too much light intensity, there is reduced photosynthesis, a reduction in the amount of pigment, smaller leaves, smaller flowers, and burning or desiccation of leaf and flower areas. In addition, the temperature increases with elevated light intensity, causing an excessive increase in the rate of cellular respiration with depletion of the food supply (simple sugar). Leaves become bleached and yellow.

Light Duration and Plant Growth

In most plants, the rate of growth is directly related to the amount of light received, because photosynthesis occurs only in the presence of light. The amount of light received by a plant is a function of intensity times duration. Plants growing during the long days, short nights, and high light of summer receive more light than plants growing under the short days, long nights, and poor light of winter. Hence, plant growth is often reduced during winter greenhouse production.

Plants also respond to the length of daylight versus the length of darkness in other ways. Such responses are called photoperiodic responses and include flower initiation, tuber and bulb formation, bract coloration, and plantlet formation.

Flowering plants are divided into several photoperiodic response categories. The three major categories will be discussed. First, short-day plants or SDP (e.g., poinsettias and chrysanthemums), switch from vegetative to reproductive growth when the days become shorter and the nights become longer. Second, long-day plants or LDP (e.g., asters and tuberous begonias), initiate flowers when the day length becomes longer and the nights become shorter.

Scientists have proven that the length of the night actually controls the photoperiodic response in plants. Each plant type and each cultivated variety has its own critical day length or number of hours of darkness that must be met before the plant switches to reproduction. Spinach, for example, is a long-day plant with a critical day length of 13 hours, or night length of 11 hours, before it will bloom and set seed.

The third category is that of day-neutral plants which are not directly affected by day length. Such plants will initiate and develop flower buds as long as there is enough day length or light for sufficient photosynthesis to produce good growth. Some examples of day-neutral plants are African violets, roses, and tomatoes.

Artificially lengthening the photoperiod by using artificial lights or shortening the photoperiod by pulling black cloth over the plant encourages plants to bloom during times of the year when they would normally be growing vegetatively. By manipulating the amount of light available (depending on type of plant, cultivated variety, and plant photoperiodic response category), the greenhouse grower can time crops to bring them into bloom for peak demand periods, such as holidays.

Light Quality and Plant Growth

Light quality refers to the wavelength or color of light. Optimum photosynthesis occurs in red and blue light. Not all wavelengths of light are useful for photosynthesis. Light wavelength is measured in a unit called a nanometer (nm). See Figure 10.1.

Ultraviolet light has very short wavelengths of less than 430 nm and is invisible. Excessive ultraviolet radiation can reduce photosynthetic activity and cause sunscald. Since plants grown in high altitudes receive high ultraviolet exposure, their growth is sometimes stunted. Glass screens out most ultraviolet light and all light shorter than 325 nm.

Visible or white light (390 to 760) is preferred for growing plants. White light is a combination of violet, blue, green, yellow, orange, and red light.

Blue light has wavelengths between 422 and 492 nm. When plants are grown with only blue light, the plants are shorter and darker and exhibit hardened tissues. Photosynthetic activity is high when exposed to blue light. Phototropism, or stem response toward light coming from one direction, is very evident.

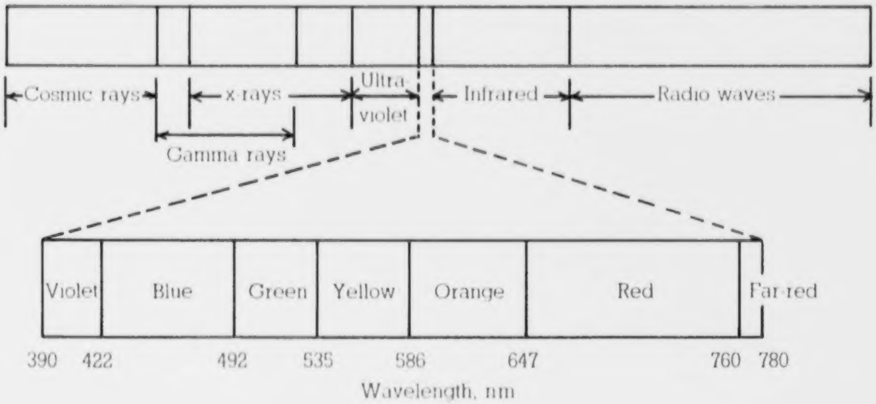
Green light has wavelengths between 492 and 535 nm. Photosynthesis is very low at this wavelength.

Red light has wavelengths between 647 and 760 nm. Photosynthetic activity is very high under red light conditions. Plants grown only in red light have soft growth and long internodes resulting in tall plants. Red light promotes seed germination and photoperiodic responses in long-day plants.

Far-red light has wavelengths between 760 and 780 nm and is important in triggering photoperiodic responses. Flowering of short-day plants is promoted by far-red light, while flowering of long-day plants is inhibited.

Infrared light wavelengths are above 780 nm. Infrared light is invisible and not involved in plant processes, but it does affect heat transfer. Infrared radiation greater than 1,000 nm causes the plant to overheat, the stomata to close to conserve water, and photosynthesis to stop.

Figure 10.1 - Light Wavelength



Effects of Temperature on Photosynthesis

Temperature is an important environmental factor that influences the rate of photosynthesis, respiration, and transpiration in the plant. Temperature dictates the speed at which chemical reactions take place within the plant; increased temperature results in increased reaction rates. Temperature affects photosynthesis at three critical levels: minimum temperature, the level below which no growth occurs; optimum temperature, when plant growth is the greatest; and maximum temperature, the level above which no plant growth occurs.

Temperature affects the formation of carbohydrates in the photosynthesis process. In most plants the rate of photosynthesis increases as the temperature increases until the temperature reaches 95°F (35°C). At 95°F, the rate of photosynthesis drops very quickly, then stops because enzymes involved in the process are deactivated. The optimum temperature range for photosynthesis to occur is between 50°F and 75°F (10°C and 24°C) for most plants. The minimum temperature at which photosynthesis takes place varies with the plant species.

By increasing or decreasing the temperature, plant growth will be affected. At low temperatures flowering may be delayed and the rate of growth is slowed. Flower and leaf color may be intensified. Higher temperatures have the following effects on plant growth: earlier and smaller flowering than normal, smaller leaves, smaller stem diameters, reduced color of flowers, and an inhibition or delay of flowering.

Temperature and the Cellular Respiration Rate

The cellular respiration rate increases as the temperature increases. Respiration depletes the food (simple sugar) reserve that is manufactured during photosynthesis. Photosynthesis occurs only in the presence of light, while cellular respiration occurs 24 hours per day. For good plant growth, the respiration rate must not exceed the rate of photosynthesis. Respiration may be slowed at night and on cloudy days by reducing the temperature. This is usually 10°F less than the daytime optimum temperature at which the plant is grown. Temperatures close to the freezing point, about 34°F (0.5°C), slow down the rate of cellular respiration so that some plants, cut flowers, fruit, and vegetables may be stored for prolonged periods without deterioration in quality.

Water and the Plant

The decision of when to water will affect the rate of plant growth. If plants are provided with adequate amounts of water, they will grow at an optimum rate. Watering plants less often will slow down plant growth. Overwatering will decrease growth (roots become oxygen-deficient) and will provide good growing conditions for fungi such as root rot.

Water plays many important roles within the plant. One role is to maintain turgidity so that the stomata are open and CO_2 may enter the leaf. Plants will wilt when there is too little water. When the leaves are wilted, photosynthesis stops because CO_2 can no longer enter the leaf. The transpiration rate is affected by the air temperature and the available water. As temperatures increase, the rate of transpiration will increase as long as the plant can absorb water. The plant will wilt when the rate of transpiration exceeds the amount of water that can be absorbed and translocated to the leaves. Plant growth will occur at an optimum rate when water, light, and temperature are maintained at optimal levels.

Water allows nutrients to be made available to the plant. Nutrients found in the soil are water soluble. Water acts as the transporting medium that allows dissolved nutrients to be absorbed by the root hairs and then be translocated within the plant.

Effects of Gaseous Components of Air

The atmosphere is mostly made up of 78 percent nitrogen, 20.9 percent oxygen, and .03 percent carbon dioxide. Oxygen, carbon dioxide, and water vapors are the gaseous components of air essential for plant growth. Oxygen and carbon dioxide are generally found in adequate quantities in the atmosphere for plant growth, but in greenhouses CO_2 levels are often a limiting factor. Hence, greenhouse crops respond favorably to the addition of CO_2 into the air. Young plants respond more favorably than mature plants.

Deficient levels of CO_2 occur in greenhouses during the daylight hours when photosynthesis is occurring during the fall, winter, and spring months when greenhouse fans are off. As a result, plant growth slows due to insufficient levels of CO_2 available for photosynthesis. To counteract this deficiency, greenhouse managers often use a CO_2 generator to add 500 to 1,500 ppm of CO_2 to the greenhouse air at the CO_2-deficient times. Common sources of CO_2 are: decomposition of organic matter or mulches, burning of fossil fuels, liquid CO_2, and solid CO_2 (dry ice). Carbon dioxide enrichment results in increased plant growth, increased yields, and higher quality plants.

Oxygen is needed for cellular respiration to occur. Proper ventilation allows ample oxygen to enter the greenhouse. It is also important to have a proper oxygen level in the greenhouse for the complete combustion of fuel for unit heaters. Unless fresh air is supplied, the plants may be damaged because of the toxic gaseous products of incomplete combustion caused by a lack of oxygen for the heaters.

Water vapors in the greenhouse atmosphere have some important effects on plant growth. Most plants will grow best when the relative humidity is between 40 and 80 percent. If the relative humidity is higher, (80 to 100 percent) fungal diseases can be a problem. This is particularly important in the winter. Plants that are grown in low relative humidity have stunted growth, fewer new shoots and leaves, smaller flowers, and stiff, upright stems. This is because transpiration rates are higher under low humidity conditions, thus placing plants under greater water stress. Low humidity is seldom a problem except around newly taken cuttings or transplanted seedlings.

The transpiration rate can be reduced by increasing the relative humidity, even though this causes an increased risk of disease attack. The relative humidity can also be increased. Walkways and underneath the benches can be wetted to increase the relative humidity. Humidifiers are another way to increase the relative humidity. It should be noted that low relative humidity is not as frequent a problem in the greenhouse as is high humidity.

Some air pollutants will cause damage or death to plants. Plants will suffer if exposed to sulfur dioxide, ethylene, fluoride, chlorine, ammonia, pentachlorophenol fumes, creosote fumes, nitrogen dioxide, peroxyacetyl nitrate (PAN), and ozone. Ethylene is the most frequently encountered toxic gas in the greenhouse. It can be largely prevented if unit heaters are supplied with adequate amounts of fresh air to allow complete combustion of fossil fuels. Proper venting of exhaust gases from unit heaters will also prevent the build-up of ethylene and other toxic gases in the greenhouse. Creosote and pentachlorophenol are wood preservatives and should not be used in or around greenhouses.

Effects of Mineral Nutrients on Plant Growth

Mineral nutrient availability or soil fertility has a direct effect on plant growth. Fertilizers are further discussed in Lesson 18. Plants supplied with adequate levels of minerals will grow at an optimum rate. Plant growth can be reduced by limiting the minerals available to plants. Some symptoms of insufficient nutrition in plants are stunting, yellowing of leaves, and reduced flower yield.

Summary

By understanding and manipulating the environmental factors directly influencing plant growth, optimum growth of greenhouse floriculture crops may be achieved. The major environmental factors include the following: light intensity (quantity or brightness), light duration (especially its effect on the plant's photoperiodic responses), light quality or the effects of light wavelengths or color on plant development, temperature (especially its influence on photosynthesis and cellular respiration), water availability, gaseous components of the environment (particularly water vapor, CO_2 enrichment, and air pollutants which can damage or kill plants), and mineral nutrients. If any of these environmental factors is mismanaged by the greenhouse grower, then the crop being produced will show decreased quality and/or productivity.

Credits

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Plant growth can be regulated or controlled genetically by cultivar selection, physically by pruning, culturally by manipulating the environment, and chemically by applying chemical growth regulators. Growth regulators can stimulate growth, retard growth, induce rooting, increase branching, and save time, production costs, and labor.

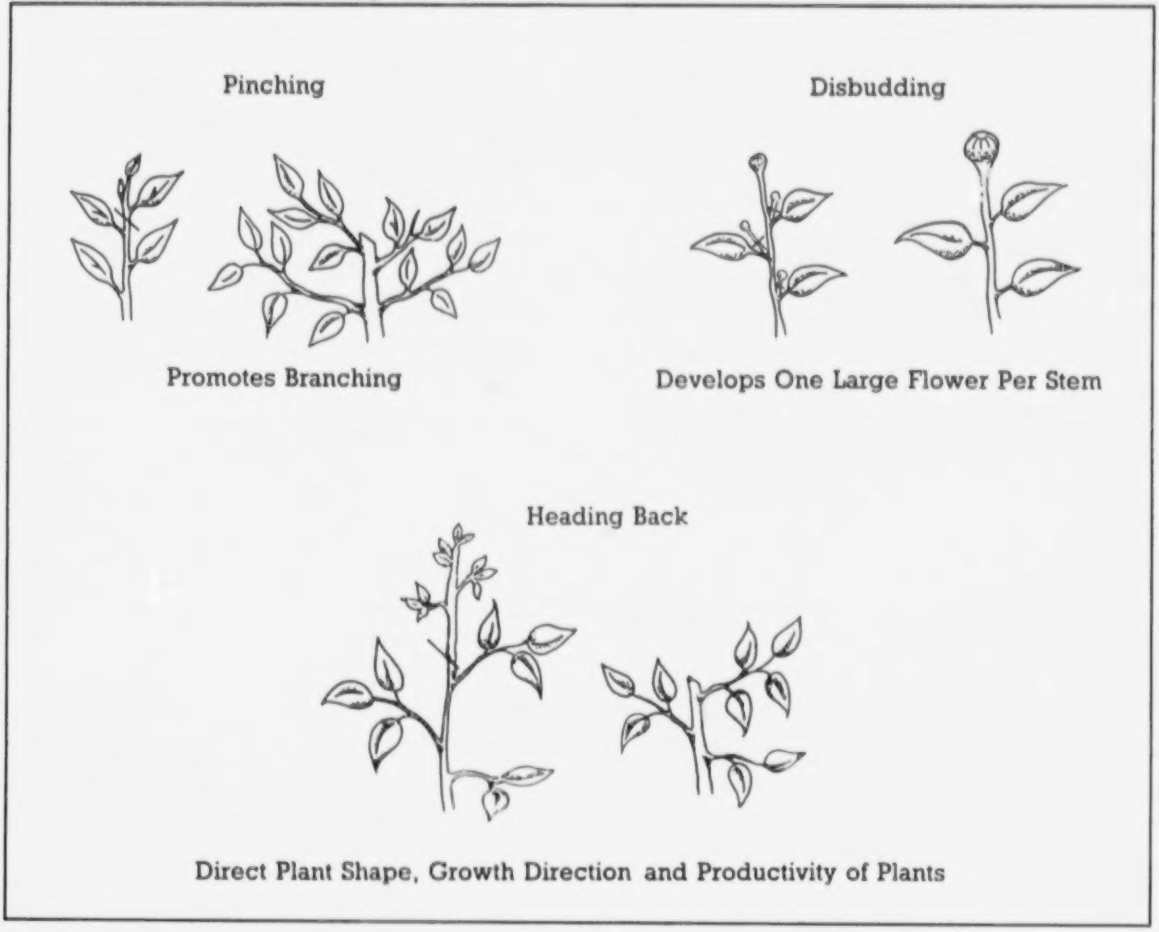
Regulating Plant Growth

Plant growth can be regulated by controlling the environment, pruning, or applying chemicals. Manipulating the environment is a cheap and effective way to control plant growth. Refer to lesson 10 for information on environmental effects (e.g., light, temperature, gaseous components of air, moisture, and mineral nutrients) on plant growth. Chemical control and pruning will be discussed in more detail in this lesson.

Pruning and Plant Growth

Pruning is a physical method of controlling plant growth. Pruning is primarily used to produce a smaller, bushier plant. It can be used to control plant shape, size, direction of growth, and flowering. It is also used to limit the number of stems on a plant. Pruning is used to physically remove dense growth from the plant. Removing the dense growth has several advantages. More air and light are allowed to come in contact with the plant. The plant can be shaped to improve its appearance. Damaged and diseased tissues are removed by pruning. By pruning a plant, flowering is encouraged. When transplanting, broken roots can be removed by pruning. Special effects to enhance the appearance of the plant are created by pruning. Pruning is done by hand so it is time-consuming and expensive.

Figure 11.1 - Greenhouse Pruning Methods



Pinching
Disbudding
Promotes Branching
Develops One Large Flower Per Stem
Heading Back
Direct Plant Shape, Growth Direction and Productivity of Plants

There are several pruning methods employed in greenhouse production. These include heading back, pinching, and disbudding. See Figure 11.1. Heading back involves the removal of excess top growth to reduce the size of a plant. This practice is common in the production of a crop such as roses that are kept year after year in the same bed.

Pinching involves the removal of the apical meristem of a plant such as poinsettia. Removal of the apical part of a stem will allow the axillary (or side) vegetative shoots to grow, resulting in a bushy, multi-branched plant. Since each branch will flower, pinching is a method to force multiple flowers from one plant.

Disbudding is the practice of removing the buds that form in the leaf axils of a plant such as a "football" mum. This forces all of the plant's energy into the production of one large apical flower.

Chemicals Used to Regulate Plant Growth

Most chemical growth regulators are hormonal in action within the plant. Hormones are chemical substances produced in very small amounts throughout the plant, particularly in meristems and young tissues. Once manufactured, hormones are translocated to another part of the plant where they have a specific effect (e.g., promotion of cell elongation in the stem). Hormones may promote or retard plant processes, depending on the particular hormone and its concentration. Hormones can also be applied to plants in a greenhouse to manipulate development.

There are five main categories of chemical growth regulators: auxins, gibberellins, cytokinins, ethylene, and growth retardants.

Auxins promote plant growth by encouraging cell division and cell enlargement or elongation. They are used primarily for promoting root formation on cuttings. Gibberellins promote plant growth through cell division and cell enlargement. They also initiate flower development. Gibberellins can be used to replace cold treatment, which is needed for breaking seed and bud dormancy, or to promote uniform development during forcing. Cytokinins enhance cell division, primarily in axillary buds. They are used in production of plant tissue cultures. Ethylene is a height retardant that promotes flowering and color formation in fruit and causes fruit ripening.

Growth retardants reduce cell division and cell elongation. They shorten the length of branches, increase chlorophyll concentration, and promote early flower formation. Some growth retardants are used as a way to chemically pinch plants so that lateral branching is encouraged.

When using these chemicals, follow label directions exactly for best results. Remember that growth regulators should not be thought of as substitutes for good growing practices.

Summary

Plant growth may be controlled by choosing cultivated varieties genetically limited as to size and growth habit. The greenhouse grower may physically control growth by pruning, pinching, and disbudding plants. In addition, chemicals may be applied to plants to regulate their growth. These chemicals include auxins, gibberellins, cytokinins, ethylene, and growth retardants. Manipulating the environment is a cheap and effective way to control plant growth.

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In order to provide optimal cultural care, the student must be able to recognize and identify plants important to the Missouri floriculture industry. These 98 important plants are categorized as follows: bedding plants, house plants, container-grown flowering plants, cut flower/foliage plants, and perennial plants.

Note that each important plant is listed by both its common name and scientific name. While the common name often varies from place to place, the scientific name is based on the Latin language (which is unchanging) and identifies the same plant no matter where it grows geographically. The first word in the scientific name denotes the plant's classification according to genus name, which is always capitalized. The second, and sometimes the third, word denotes the plant's species name, which is lower case. When included as part of the scientific name, the cultivar name is highlighted by single quotation marks or by "cv." Scientific names are either underlined or printed in italics.

21 Important Bedding Plants

AGERATUM (Ageratum mexicanum) plants are long-blooming summer annuals that grow from 6 to 24 inches tall. Fluffy ageratum blossoms are usually a true blue color, although they may be lavender, white, or pink. Ageratums flourish in a sunny location and are used as fresh cut material or for dried bouquets. They are often found in flower borders, edgings, and mass plantings.

CABBAGE (Brassica oleracea capitata) plants are a cool season vegetable. For maximum growth, it is important to use transplants started from seed; set them out in the garden about March 15 (in central Missouri). Cabbages grow best in full sun with ample moisture. The leaves of this vegetable are prone to attack by caterpillars and other insects; insecticides must be applied periodically to kill these pests. In Missouri, cabbage is grown as an annual.

CELOSIA or COCKSCOMB (Celosia cristata) plants grow up to 18 inches tall. Celosia may be directly seeded into the flower garden as soon as all danger of frost is over or started from transplants. Flourishing in full sun, celosia flowers are available in red, gold, and many other colors. Crested celosia flowers look like a rooster's comb and are long-lasting in fresh arrangements. A second type of celosia bears a plume-like flower. Celosia is very easy to dry for winter bouquets and arrangements. Celosia are annuals.

COLEUS (Coleus x hybridus) plants have very colorful leaves and unattractive flowers. Pinching off the terminal flowers will stimulate more foliage growth and keep the plants growing compactly. Coleus may be started from seed or from rooted cuttings and should be protected from full sunlight. Coleus are annual plants which are easy to grow.

DUSTY MILLER (Senecio cineraria) plants are perennials grown for their finely divided silver to silver-white foliage. This easy-to-grow plant is both heat and drought tolerant. Often used in edging and border plantings, Dusty Miller foliage may also be cut to add color and texture to fresh flower arrangements.

GERANIUM (Pelargonium x hortorum) plants are vigorous, trouble-free, and prefer full sun. They are often grown in beds, window boxes, patio containers, and hanging baskets. Geraniums may be started from seed or from rooted cuttings. Although available in many colors and color combinations, the solid red geranium is the most popular flower color. These plants will continue to bloom throughout the summer if the old blossoms are removed. After growing outdoors as a summer annual, the geranium may be planted ,in a container to winter indoors on a sunny window sill where it will bloom freely.

IMPATIENS or SULTANA (Impatiens hybrid) plants grow well in the shade or semi-shade and are literally covered with blooms from spring until frost. Impatiens flowers are available in a vast array of brilliant colors and color combinations. The New Guinea impatiens is a new type of impatiens with variegated foliage and huge blooms (up to 3 inches in diameter). The New Guinea impatiens grows best in full sun. Impatiens are often displayed in window boxes and hanging baskets.

IVY GERANIUM (Pelargonium peltatum) plants are low-growing, vigorous trailers with leaves that are shaped like ivy leaves. The ivy geranium makes a striking show of color in a hanging basket. Large clusters of white, pink, or lavender flowers appear mostly in the spring. As flowering occurs throughout the summer, the dead flower heads must constantly be removed to encourage continued blooming. In late summer, watering is reduced as the leaves start to yellow and dry. Store the geranium in its container in a frost-free, dark place and water sparingly. When new growth appears in spring, gradually increase the water supply and fertilize when the new growth is well-started. Stem cuttings may be taken in the fall and rooted, and the young plants can be grown indoors until spring.

MARIGOLD (Tagetes sp.) plants are easy-to-grow annual flowering plants with brilliant yellow to red blossoms. These colorful plants flourish in full sun and produce long-lasting cut flowers. Marigolds may be directly seeded into the flower garden or started indoors and then transplanted after the frost-free date. Marigolds will bloom continuously until frost. French marigolds are dwarf plants with small flowers. African marigolds, which produce the largest double blooms (up to 6 inches across), are ideal for cutting. Marigolds are often planted in vegetable gardens to repel nematodes.

NASTURTIUM (Tropaeolum majus) plants have long-stemmed flowers of bright red, orange, and yellow. Nasturtiums flower from early summer until frost. The stem is attached to the middle of light green leaves. Both the flowers and leaves may be added to salads. This quick-growing plant flourishes in full sun and cool temperatures. Seed is sown directly in the flower garden after the frost-free date. These annuals are easy to grow in beds, edgings, hanging baskets, and as ground cover.

PANSY (Viola x Wittrockiana) plants are grown in Missouri as annuals in low beds and flower borders. Plants are about 7 inches tall and are easily grown. Generally, starters are transplanted outdoors in full or semi-shade in early spring. Although pansies enjoy cool weather, they may thrive over the summer if kept mulched and moist. Pansy flowers can measure up to 4 inches in diameter and come in a wide range of colors and color combinations, some plain and some with interesting "face markings."

PEPPER, GREEN (Capsicum fruitescens) plants produce sweet peppers which are green in color when young and eventually ripen to red. Sweet green peppers are rich in vitamin C. Start peppers from seed and transplant to a sunny spot in the garden, after all danger of frost is past.

PETUNIA (Petunia x hybrida) plants are one of the most common annual bedding plants, growing up to 12 inches tall. Petunia flowers are possible in many colors and color combinations and may be plain-edged or ruffled. There are two main types of petunias. Grandiflora have large, individually showy flowers up to 4 inches in diameter. Multiflora has smaller flowers but produce more of them for a greater floral display. Petunias are often planted in window boxes, patio containers, hanging baskets, and flower beds.

ROSE MOSS (Portulaca grandiflora) plants spread and form a ground-covering carpet. Plants should be grown in full sun; these annuals thrive in heat and are drought-tolerant. Rose moss has succulent needle-shaped leaves. The ruffled flowers measure up to 2 1/2 inches across and come in many brilliant colors. Many rose moss varieties close their blossoms in the afternoon and on cloudy days.

SALVIA (Salvia splendens) plants have long, dense flower spikes which bloom from early summer until frost. Flower colors include brilliant red, rose, pink, salmon, lilac, violet, purple, and white. Salvia blooms attract hummingbirds. Salvia may be started indoors from seed and transplanted to the flower garden after the frost-free date; it is an annual that grows well in full sun.

SWEET ALYSSUM (Lobularia maritima) plants are short (up to 8 inches tall) and spreading (up to 12 inches across) annuals. Sweet alyssum may be planted in the sun or in partial shade and favors cool weather. This plant is covered with tiny fragrant flowers that smell like honey. Flowers may be white, rose, pink, or purple, and the plant will rebloom if the old flowers are trimmed. The low spreading growth habit of sweet alyssum makes it ideal for borders and edgings.

TOMATO (Lycopersicum esculentum) plants are grown as annuals in Missouri. The tomato is the most popular home garden vegetable. Tomato seeds may be started indoors about 6 weeks before the frost-free date when they are transplanted to the garden. Tomatoes are of two growth types. Indeterminate tomatoes continue to grow and simultaneously bear fruit until frost. Determinate tomatoes stay compact. For best results, choose tomato varieties resistant to Verticillium Wilt, Fusarium Wilt, nematodes, and Tobacco Mosaic Virus. Plant tomatoes in full sun and provide them with plenty of moisture.

VERBENA (Verbena x hybrida) plants are low-growing annuals (about 15 inches tall) that provide an excellent ground cover. Verbena is also grown in beds, borders, edgings, and hanging baskets. Verbena has brilliantly colored, fragrant blooms that usually have white "eyes." Seeds may be started indoors in March for transplanting outdoors in full sun. Blooming will commence in mid-summer with rounded clusters of small, tubular flowers. Verbena can withstand dry conditions.

VINCA (Catharanthus roseus) plants are annuals that will provide a continuous show of colorful booms until frost even in very hot, very dry climates. Annual vinca may be of two growth habits: dwarf or creeping. Both are used in semi-shady to full sun beds as ground covers; the creeping type makes attractive hanging baskets. A January sowing of seed in the greenhouse will produce blooming plants in June. Several colors are available, including: pure white, white with red eye, rosy pink, and pink with rose eye. Vinca needs minimum care.

WAX BEGONIA (Begonia x semperflorens) plants have fibrous roots and are from 8 to 12 inches tall. The leaves are a waxy green, bronze, or variegated. These plants grow in a mound shape in shade or partial shade. Red, pink, or white flowers cover the plant all summer long. Wax begonias are prized for patio planters, window boxes, garden beds, and as house plants.

ZINNIA (Zinnia elegans) plants are directly seeded in the flower garden and are extremely quick growers. Plants vary in size from 4 inches to over 3 feet tall. Zinnias grow best in full sun, warm temperatures, and well-drained soil. Zinnias come in all colors, and many color combinations except blue. Zinnia blossoms may be up to 8 inches in diameter. Cutting the blooms prunes the plants to encourage fullness and blooms. Annual zinnias are often planted in beds, borders, and patio containers.

30 Important House Plants

AFRICAN VIOLET (Saintpaulia ionantha) is the most popular flowering house plant in America. This plant has velvety, fleshy leaves growing in spreading rosettes. The African violet has a short stem and relatively small roots. Single or double blossoms in many shades of purple, blue, pink, red, white, bicolors, and multicolors adorn this plant. Flowers appear through the year because the African violet is a day-neutral plant. This plant likes warm temperatures, partial shade, and high humidity; it grows well in an indoor light garden.

ALUMINUM PLANT (Pilea cadierei) has silvery markings on quilted dark green leaves that provide this plant with its common name. Regular pinching of the stem tips encourages branching and foliage fullness. The aluminum plant can be damaged by direct sunlight. It flourishes in average to warm temperatures and uniformly moist soil. This easy-to-grow plant will normally lose its oldest leaves as it ages. The aluminum plant adapts well to containers or hanging baskets.

BOSTON FERN (Nephrolepsis exaltata 'Bostoniensis') plants may have 3-feet long, arched fronds (a leaf consisting of many separate leaflets borne on one leafstalk) that cascade from the rich green rosette growth habit. Numerous flat 3- to 4-inch long leaflets comprise the frond. This fern was the most popular house plant, as well as a trademark of English life, during the Victorian era. It flourishes in a cool location with high humidity. It grows best in bright but not direct light, and in uniformly moist soil. The Boston fern is ideal for displaying on a pedestal or in a hanging basket where the fronds can cascade gracefully.

BURRO'S TAIL (Sedum morganianum) is a slow-growing perennial sedum with long stems that droop over the edge of the container. Because of its pendulous stems, burro's tail plant is usually grown in hanging baskets. Each stem is covered with numerous small, gray-green, fleshy, teardrop-shaped leaves. This plant may be grown outdoors during the summer and indoors throughout the year. It will tolerate a wide range of temperatures (40°-100°F) and flourishes in full sun and moderate moisture.

CALADIUM (Caladium hortulanum) plants are started from tubers and are grown for their large, colorful foliage. This easy-to-grow perennial produces red, pink, white, green, or multi-colored leaves, creating a colorful display in containers or in shady garden beds. Masses of leaves continue to grow until frost, when the tubers must be dug and stored indoors. In late winter or early spring, the tubers may be planted in containers and will produce a foliage display about eight weeks later. Caladiums grow best with warm temperatures and ample water.

CORN PLANT DRACAENA (Dracaena fragrans massangeana) has leaves that look like those of a field corn plant (i.e., long, broad, and green with creamy yellow central stripes). Cool temperatures will cause leaf drop. The corn plant dracaena grows 6 feet tall and flourishes in bright, but not direct, sunlight and high humidity.

CROTON (Codiaeum variegatum pictum) plants are available in over 100 varieties. They are grown for their leaves, which come in many striking colors and color combinations including copper, orange, yellow, green, pink, red, ivory, and brown. Often the leaves are patterned with multicolored spots and blotches; a single croton plant may have many different colored leaves. Croton needs warmth and direct sunlight to bring out the richness of the leaf hues. They grow rapidly to become 5-foot tall shrubs. Hence, periodic pruning is required to keep the croton a reasonable size.

CROWN OF THORNS (Euphorbia splendens) plant is an extremely thorny branching shrub growing about 3 feet tall. One-half-inch long, bright green leaves fall off the stems if the plant receives insufficient water. Small red bracts surround the tiny yellow flowers that bloom on the tips of the branches. This perennial thrives in direct sunlight and moderate moisture. Propagate by stem cuttings taken during spring and summer.

DWARF SCHEFFLERA (Schefflera arbicola) is a perennial plant similar in general form to the larger schefflera, although it is much smaller and more compact. The foliage of this perennial is smaller and darker green than Brassaia actinophylla.

EMERALD RIPPLE PEPEROMIA (Peperomia caperata 'Emerald Ripple') plants have dark green, glossy, heart-shaped leaves with deeply wrinkled surfaces. This low-growing foliage plant is especially attractive in terrariums and dish gardens. The emerald ripple grows about 4 inches tall and about 5 inches across. In spring, this peperomia sends up white flower spikes that look like mouse tails. It is important to avoid overwatering these perennials, especially during the winter.

ENGLISH IVY (Hedera helix) leaves usually have three points, although the size and shape of leaves may vary. This versatile trailing vine may be planted indoors in hanging baskets or outdoors as a ground cover. It is a hardy perennial that grows best in full sun or bright indirect light. The leaves are generally solid green, but may be variegated. English ivy readily propagates by stem cuttings.

FUCHSIA (Fuchsia hybrida) plants have bell-shaped flowers with gracefully curving sepals, which are reminiscent of women's fashionable earrings. Fuchsia flowers are often bi-colored (e.g., red and white, red and magenta, or pink and white). The plant has two growth habits: upright mounded plants for containers and cascading plants for hanging baskets. Fuchsia blooms indoors throughout the winter and outdoors in the shade during the late summer. The leaves are about 2 inches long, pointed at the ends, and oval with slightly toothed margins. Fuchsia grows best in bright light with some direct sunshine, ample moisture, and cool temperatures.

GERMAN IVY (Senecio mikanioides) is also known as parlor ivy and is a fast-growing perennial vine. German ivy has 2- to 4-inch long multilobed leaves reminiscent of English ivy foliage. This plant must be trimmed regularly to encourage fullness and denseness. This easy-to-grow, thickly foliaged plant is attractive in containers, in hanging baskets, or climbing a pole. German ivy grows best in average to cool temperatures, partial shade, and uniformly moist soil.

GOLD-EDGED SNAKE PLANT or MOTHER-IN-LAW TONGUE (Sansevieria trifasciata 'Laurentii') is very easy to grow. The stiff upright leaves are about 30 inches long and up to 3 inches wide. They are marked with horizontally zig-zagging grayish-white or pale green stripes, similar to a snake's pattern. The gold-edged mother-in-law tongue plant has leaves with broad yellow margins. Sansevierias will thrive in full sunlight or in a northern window. They like warm temperatures and moderate moisture. The 'Laurentii' variety can only be propagated by root divisions, for this is the only way to maintain the gold edging.

GOLDEN POTHOS or DEVIL'S IVY (Scindapsus aureus) plant is a trailing vine with green and gold variegated waxy leaves. Devil's ivy leaves are similar in size and shape to the philodendron. Stems of this plant root wherever they touch soil or if placed in water. Growing tips must be pinched periodically to encourage fullness. Devil's ivy is one of the most popular vines for planting in hanging baskets or for climbing totem poles. This low maintenance plant grows well under ordinary home conditions.

HEARTLEAF PHILODENDRON (Philodendron scandens oxycardium) is the most popular and most easily grown of all foliage house plants. It has heart-shaped leaves that are shiny, deep green. This versatile and tolerant trailing plant must be trimmed periodically to encourage branching and additional foliage growth. A rapid grower, it is attractive in a planter, in a hanging basket, or climbing up a totem pole. Philodendron thrives in average to warm temperature and bright, indirect light. The perennial philodendron is easily propagated by stem cuttings.

INDIA-RUBBER PLANT (Ficus elastica 'Decora') is one of the most common and easily grown foliage house plants. It adapts well to normal household conditions, since it thrives in temperatures above 50°F and in limited direct sunshine. Many large, glossy dark-green or variegated leaves are produced; before opening, these leaves are enclosed in dark red sheaths. Frequent, gentle washing with lukewarm water will insure the shiny appearance of the leaves. The India-rubber tree is widely used to decorate office building interiors.

JADE PLANT (Crassula argentea) is a succulent perennial plant with fleshy, spoon-shaped leaves about 1 to 2 inches long in glossy jade green, often marked with combinations of white, yellow, red, or other colors. The jade plant thrives in moderate direct sunlight and moderate amounts of water. Occasionally small pinkish-white flowers will be produced. A young jade plant is an interesting addition to a dish garden that will eventually grow into a miniature tree.

MEDICINE PLANT (Aloe vera) is used for treating minor cuts and burns by applying the sap from a freshly-cut leaf to the injury. These pointed, fleshy leaves, which may grow up to 12 inches in length, are green with white flecks. Aloe is a perennial and is easily propagated by separating offshoots from the parent plant.

NORFOLK ISLAND PINE (Araucaria heterophylla) is a perennial evergreen with needles less than one inch long. The branches are gracefully arranged in tiers along the stem, giving the plant the appearance of a miniature Christmas tree. This slow-growing pine grows best in medium light and high humidity. The pine will drop its needle leaves if grown under low light conditions.

POLKA DOT PLANT (Hypoestes phyllostachya) is also known as the freckle-face plant because it has dark green leaves speckled with tiny white or pink spots. These mound-shaped plants grow about 12 inches tall, and many branches come from the base. They are container-grown indoors, or can be grown outdoors in flower borders, preferring full sun or semi-shade. This easy-to-grow greenhouse perennial needs periodic pinching of the stem tips in order to encourage fullness and compactness.

PRAYER PLANT (Maranta leuconeura 'Kerchoveana') is also known as maranta and derives its common name of prayer plant from the orientation of the leaves at night. When in darkness, the leaves of the prayer plant fold lengthwise in a shut position that looks like hands in prayer. At all other times, the leaves are unfolded horizontally. The 'Kerchoveana' variety grows about 8 inches tall with grayish-green leaves containing reddish spots that resemble animal tracks running lengthwise on the leaves. Maranta thrives in indirect light, warm temperature, and uniformly moist soil.

SPIDER PLANT (Chlorophytum commosum) is a perennial that is also known as the airplane plant or the ribbon plant. Small plantlets, commonly called "spiders" or "airplanes," grow on spindly stems; each plantlet may be separated and planted in a growing medium where it will quickly root. This plant grows in a rosette form with long grasslike leaves of solid green, creamy yellow and green stripes, or green with white bands down the center. This easy-to-grow house plant has a cascading form which is popular in hanging baskets.

SPOTTED DUMBCANE (Dieffenbachia maculata) grows as a single-stem plant up to 8 feet tall. The large leaves may be green or yellow, often with contrasting spots, veins, or edgings. Overwatering will cause stem rot. Dieffenbachia is called dumbcane because the stem and foliage contain calcium oxalate, a chemical that when eaten causes the mouth and throat to swell, making speech impossible for a day. Dieffenbachia is a perennial plant, especially suited for a large display.

SPRENGERI "FERN" (Asparagus densiflorus 'Sprengeri') is misnamed because it is a true asparagus with cascading, vining stems and feathery, short, green, needle-like leaves. Sprengeri foliage is often used in fresh flower arrangements as a filler. It is important to keep the soil uniformly moist, but not wet, and to provide plenty of light while avoiding full sun. This perennial plant thrives in high humidity, so mist often.

STRAWBERRY BEGONIA (Saxifraga sarmentosa) plant grows a rosette of dark green rounded leaves. This plant spreads by growing long runners, like strawberries, with new plantlets on the runner tip ends. In summer, erect stems bear clusters of white blooms. The strawberry begonia is especially attractive when grown in a hanging basket or on a pedestal. It thrives in cool temperatures.

UMBRELLA PLANT (Brassaia actinophylla) foliage originates from a central point at the end of a stem and radiates out like an open umbrella. The large, light green leaves are glossy and oval-shaped. The perennial stems are woody and can grow 5 feet tall or more. The umbrella plant flourishes in bright light, but not direct sunlight. It is especially prone to spider mite attack; tiny yellow or tan spots on the leaves are scars from mite feedings.

VARIEGATED PEPEROMIA (Peperomia obtusifolia 'Variegata') is a 10-inch tall plant that has light green leaves irregularly bordered with creamy white. Each leaf is about 2-3 inches long, heavy, and thick; the weight of the leaves forces the plant's stem to curve. The variegated peperomia is a very easy-to-grow perennial that prefers bright, indirect light and warm temperatures. It is important to avoid overwatering this peperomia.

WANDERING JEW (Zebrina pendula) is one of the toughest and most popular houseplants, especially for hanging baskets. This perennial is a fast-growing, trailing vine with pairs of leaves appearing along the stems. The leaves have green and silver lengthwise stripes, with purple undersides. Bright light is required to bring out the richness of the leaf hue. Wandering Jew flowers are insignificant. These plants required minimum care and are easily propagated by stem cuttings.

WAX PLANT (Hoya carnosa) grows many trailing vines. The cascading and climbing growth habit of the wax plant make it ideal for striking hanging basket displays. Thick, fleshy leaves grow in pairs along the stems. These smooth, waxy leaves may be solid green or variegated with many colors. Clusters of tiny, sweet-scented, star-shaped flowers adorn this plant for many weeks; they look as if they are made of wax. This long-living perennial flourishes in bright indirect to direct sunlight and a well-drained soil mixture.

15 Important Container-Grown Flowering Plants

AMARYLLIS (Hippeastrum hybrid) plants are usually started from large bulbs, although they may be started from seed. This indoor perennial is grown for its striking clusters of blooms that appear every year, generally during the winter. Huge, flaring, trumpet-shaped flowers (each up to 9 inches across) are borne in cluster of four atop a thick, tall green stalk. Flower colors include red, pink, salmon, white, and striped. After blooming, large strap-like leaves appear.

AZALEA (Rhododendron sp.) plants are perennial shrubs about 18 inches tall and 18 inches wide. Azalea leaves are one inch long, oval, and dark green. Showy, funnel-shaped blooms occur from Valentine's Day through Easter, as a result of greenhouse forcing. Flower colors include red, pink, and white. Azalea plants grow best during cool weather in a high acid soil, such as peat moss. Ample watering is required to avoid leaf discoloration.

CALCEOLARIA or POCKETBOOK PLANT (Calceolaria herbeohybrida) plants are usually covered with clusters of blooms that look like little pocketbooks. The common bloom colors are red, orange, and yellow, often with contrasting patterns and/or spotted markings. A September sowing in the greenhouse will produce flowers in the winter; the plant flowers from late January through April. Calceolaria is grown as an annual and thrives in cool temperatures.

CYCLAMEN (Cyclamen persicum) plants are available at Christmas, Valentine's Day, and during the spring. Seed sown in May will bloom for Christmas. The heart-shaped leaves grow in rosette form and are often variegated light and dark green. Cyclamen forms a corm that can be saved for the purpose of reblooming the plant. It grows best in a cool greenhouse (50°F night temperature) and bright light. Exotic-looking flowers, up to 4 inches across, are held above the foliage by long stems. Flower colors of this annual plant may be purple, lavender, white, red, pink, or white with a pink eye.

EASTER LILY (Lilium longiflorum) plants are very popular, especially at Easter. A tall sturdy stem grows from a large bulb; atop this flower stalk are large, white, trumpet-shaped blooms; each stalk may have up to 5 blooms. Long, green strap-like leaves are found on this tender perennial. In southern states, Easter lilies may be planted outdoors in a protected location after the frost-free date. In this manner it is often possible that the Easter lily will bloom the following year.

EXACUM or PERSIAN VIOLET (Exacum affine) is one of the most fragrant annual plants grown in the greenhouse. It is also known as the German violet and is sometimes grown in shady flower beds during the summer. Exacum grows about 12 inches tall and has waxy foliage; it is often covered with small blue, purple, or white flowers with prominent yellow stamens or "eyes."

FLORIST'S CHRYSANTHEMUM or POT MUM (Chrysanthemum morifolium) plants may be forced to bloom in the greenhouse every month of the year. In fact, the mum is the most common container-grown greenhouse flowering plant for year-round sales. It is started from cuttings. Because it is a short-day plant, application of black cloth over the beds during periods of long light duration is needed to trigger blooming. Mums come in many colors, including bronze, yellow, gold, orange, red, rose, pink, white, and lavender. The large, daisy-like flowers vary in form: single, anemone, pompon, or button.

FLORIST'S CINERARIA (Senecio x hybridus) plants are commonly used for window displays. Many long-lasting, bright-colored and bicolored flowers, often with contrasting eyes, cover the top of this plant. Seeds started in September will bloom the following winter. Cineraria is an easy-to-grow annual that prefers a cool greenhouse.

GLOXINIA (Sinningia speciosa) plants are started from tubers or seed and produce either single or double, large, open, bell-shaped flowers. The flowers come in jewel-like colors of white, pink, red, purple, or bicolors. Some flowers are speckled, while others have contrasting borders. Often the flowers literally cover the large, dark green, velvety leaves. Gloxinia thrives in a warm, humid, and semi-shady greenhouse. After the leaves turn yellow in autumn, remove them and store the tubers in a cool, dry place. These perennials may be restarted in February for late spring bloom.

HIBISCUS (Hibiscus rosa-sinensis) plants may be container-grown or grown outdoors in a sunny garden. This husky, fast-growing perennial shrub has large glossy green leaves and is well-suited for summer borders or hedges. Large (up to 9 inches) flowers of white, yellow, orange, pink, or red adorn this easy-to-grow plant. Flowers, which are open for one day, are either single or double; single flowers are funnel-shaped and have prominent yellow stamens.

HYDRANGEA (Hydrangea macrophylla) plants are perennials that are popular at Mother's Day and Easter. They are grown for their four-petal flowers borne in globe-shaped flower heads; each head may be up to 8 inches in diameter. Hydrangea flowers come in white, pink, or blue, depending upon soil acidity. This bushy plant has woody stems.

KALANCHOE (Kalanchoe blossfeldiana) are long-lived plants with succulent, waxy green foliage. This compact plant is grown as an annual in the greenhouse. Kalanchoe is a short-day plant, which usually blooms in winter. Large clusters of small flowers in orange, pink, or yellow provide a colorful display. Propagation is by cuttings.

POINSETTIA (Euphorbia pulcherrima) is the most popular flowering container-grown plant sold during the Christmas season. Large colorful modified leaves, called bracts, surround the small yellow "true" flowers in the center of the display. The bracts are often red and, under proper conditions, may last for several months. Besides red, other bract colors include white, pink, marbled pink and white, and red with white spots. Grown as an annual in the greenhouse, this plant must have short days to trigger blooming. In nature, poinsettia is a perennial shrub.

PRIMROSE or PRIMULA (Primula sp.) plants produce extremely showy indoor winter blooms. Flower clusters rise from the center of rosette foliage; colors may be white, red, orange, yellow, purple, or blue, with or without a prominent yellow "eye." The foliage may be 12 inches across; leaves are strap-shaped. This low-growing plant, treated as an annual in the greenhouse but as a perennial in nature, flourishes in cool temperature and semi-shade.

RIEGER BEGONIA (Begonia hiemalis) plants were introduced in 1954 to the floriculture industry by Otto Rieger of Germany. Bred to be more disease-resistant and to produce more flowers, the Rieger begonia is about 12 inches tall with glossy green foliage. Red, orange, yellow, pink, or white blossoms may be either single or double flowers. The plant is propagated by leaf or stem cuttings. In general, Rieger begonias are prone to diseases, especially powdery mildew fungus and bacterial leaf spot. This plant also makes a striking appearance in hanging baskets.

20 Important Cut Flower/Foliage Plants

BIRD OF PARADISE (Strelitzia reginae) plants have huge, exotic flowers with iridescent orange and bright blue petals. Each striking flower tops a tall, sturdy stem and is reminiscent of a bird in flight. Long-lasting, bird of paradise flowers are prized for large flower arrangements. Bird of paradise plants grow up to 6 feet tall and have long bluish-green leaves (similar to banana plants, which are in the same family). It is a perennial plant by nature.

CARNATION (Dianthus caryophyllus) plants are grown in ground beds in cool greenhouses. Florist carnations have 3-inch blooms with multi-petals borne on stiff stems. Carnation flowers range in many colors; the foliage is silvery blue-green. Carnation blooms often have a spicy fragrance and are long-lasting in arrangements.

CATTLEYA ORCHID (Hybrid Cattleya) plants are container-grown and produce large blooms, which are prized in corsages. Cattleya blooms range from 2 1/2 to 6 inches in diameter. A vast array of colors is possible with this orchid, from pure white through yellow, red, and lavender, as well as white with purple lips and yellow with purple lips. Cattleya plants enjoy bright light (not direct sunshine), high humidity, and warm temperature; they thrive under greenhouse conditions. Different cattleya varieties will produce long-lasting cut flowers all year. Orchids are perennials by nature.

CYMBIDIUM ORCHID (Cymbidium) plants are container-grown and produce long stalks with as many as 20 large flowers (each nearly 5 inches in diameter). Long-lasting cymbidiums are available in many pastel colors. Cymbidiums are grown in the greenhouse for sale during the spring season; they are popular for Easter and Mother's Day corsages, as well as for wedding bouquets. This perennial grows best in cool temperatures.

DAFFODIL (Narcissus pseudo-narcissus) plants are container-grown in bulb pans, pots, flats, or pallets, and may be forced into bloom in the greenhouse between mid-December until April. Bright yellow or white trumpet-like blossoms on sturdy stems make the daffodil a favorite cut flower for winter and spring arrangements. During the forcing process, daffodil bulbs must be planted in a container and placed in a cool (48°F/9°C), dark place for 15 weeks. Then the containers of bulbs are brought into a 57°F (14°C) greenhouse until flowering occurs.

EMERALD and JADE (Chamaedorea sp.) plants are palms that are field-grown for their greenery. Jade or emerald foliage is cut and used in larger flower arrangements and in funeral pieces. Leaflets on the fronds of jade are wider (up to 2 inches) and are glossy dark green. Emerald leaflets are narrower and are usually lighter green in color than jade. Both types thrive in low light, warm temperature, and moderate moisture conditions.

GARDEN GLADIOLUS (Gladiolus grandiflorus) plants are grown from tender corms which must be stored indoors in a cool place during the winter. Each corm produces a single flower spike; each spike may have up to 26 florets. Florets may be flat, round, triangular, orchid-like, or hooded with numerous petal shapes, including ruffled. An individual flower may measure 5 inches across. Gladioli are available in every color (except true blue) and many striking color combinations. The gladiolus is grown as an annual.

GARDENIA (Gardenia jasminoides fortuniana) plants are container-grown long-lived shrubs that grow about 30 inches tall. The leaves of this broadleaved evergreen are glossy dark green; the blooms are creamy-white and heavily scented, making them ideal for corsages. Gardenias grow best in full light, high humidity, and medium temperature greenhouse conditions. Perennial gardenia plants require strongly acidic soils.

GERBERA or TRANSVAAL DAISY (Gerbera jamesonii) plants grow about 18 inches tall in greenhouse beds, forming a basal rosette of leaves. Colorful gerbera flowers are borne one per thick stem and may be single or double. Brilliant and often large (a single flower may be 5 inches in diameter), cut gerberas will last up to two weeks in an arrangement. In Missouri, gerberas are grown as perennials in the greenhouse.

HUCKLEBERRY (Vaccinium ovatum) shrubs are grown for their long-lasting foliage which is often used in arrangements. Huckleberry leaves measure up to 2 inches long on woody stems.

HYBRID TEA ROSE (Rosa hybrida, Class Hybrid Tea) plants are grown in greenhouse ground beds. Atop long thorny stems, blooms may measure up to 6 inches across when fully open. Many colors and color combinations are possible, however; about 65 percent of the hybrid tea roses grown for cutting have red blooms. Many varieties have fragrant flowers. Sturdy, long stems are desirable. The rose is a perennial plant.

SALAL or LEMON LEAF (Gaultheria shallon) plants are grown for their long-lasting, large, glossy green leaves produced on woody stems. Individual leaves are up to 4 inches long, making them especially useful for larger arrangements.

SILVER DOLLAR GUM or EUCALYPTUS (Eucalyptus polyanthemos) plants are grown for their gray-blue foliage. Individual leaves encircle the main stems, are round to nearly heart-shaped, and grow up to 3 inches across. Strongly medicinal-scented eucalyptus foliage may be used fresh or in dried arrangements, after being preserved in glycerine and water.

SNAPDRAGON (Anthirrhinum majus) plants are grown from seed in greenhouse beds. Snapdragons grow to 3 feet tall and produce many long spikes with numerous florets. Individual flowers may be either single or double and come in many solid colors and color combinations. Florist varieties have thick, sturdy stems and are impressive in groups, especially in large arrangements. Snapdragons are long-lasting and are grown as annuals in Missouri, although they are often winter hardy in warm climates.

STATICE (Limonium sinuatum) flowers are often used by florists as everlastings in dried bouquets, although they may also be used as fresh cut material. Statice plants grow about 24 inches high, either outdoors or in the greenhouse. These annual plants produce dense, graceful sprays that grow up to 18 inches long and are covered with small, papery blossoms of many colors.

STEPHANOTIS (Stephanotis floribunda) plants are also known as Madagascar jasmine plants, and are climbing, twisting vines with shiny, thick, green leaves. Stephanotis may be grown in a container or in a ground bed. Since stephanotis plants like high temperature and high humidity, they thrive in the greenhouse environment. Stephanotis bears white, waxy, sweet-scented 2-inch tubular flowers in clusters; these flowers are ideal for bridal bouquets or for Hawaiian leis. Stephanotis is a perennial vine.

STOCK (Matthiola incana) columnar plants started from seed in the greenhouse bench or ground bed grow about 18 inches tall and produce heavy spikes of fragrant flowers. Stock flowers occur in a wide range of brilliant colors; they thrive in cool weather. Either grown outdoors or forced in a greenhouse, stock is an annual plant.

STRAWFLOWER (Helichrysum bracteatum) plants are 18-36 inches tall and are usually grown outdoors, although they may be greenhouse-grown. Brilliantly-colored strawflowers bear double, 2-inch daisy-like blooms. Strawflowers may be used in fresh cut flower arrangements, or may be dried for winter bouquets. Strawflowers belong to a plant category known as "Everlastings" (i.e., capable of being dried yet preserving their natural color) and are grown as summer annuals.

TULIP (Tulipa sp.) plants are container-grown in bulb pans, pots, flats, or pallets. They may be forced into bloom in the greenhouse between late December and early May. Many colors and color combinations help make tulips favorite flowers for winter and spring arrangements. In addition, tulips have many petal forms (e.g., single, double, fringed, lily-like, etc.) which add interest to the arrangement. Tulips may be forced into bloom in the greenhouse by planting the bulbs in a container and placing them in a cool (48°F or 9°C), dark place for 15 weeks. Then they are moved into a warm (65°F or 18°C) greenhouse until flowering occurs.

12 Important Perennial Plants

AJUGA or BUGLE WEED (Ajuga reptans) plants are carefree ground covers that grow well in shade, partial shade, or sun, creating a carpet without the need to mow. Ajuga plants are about 5 inches tall. Spikes or dense clusters of tiny white, pink, or purple flowers appear in spring and summer. The bronze-colored leaves of some ajuga species are especially prized.

CANNA (Canna indica) plants range in size from 2- to 7- feet tall, depending on the variety. Hence, they can be used either in containers or in flower borders, or even as a high living fence. Canna flowers bloom from July until frost. The flowers range in many colors and color combinations, although solid red is the most common. Cannas grow from tender rhizomes which, in Missouri, must be dug and stored during the winter.

CLEMATIS (Clematic sp.) is called the "Queen of the Climbers." Clematis flowers may measure up to 10 inches in diameter and come in many colors and shadings. Blooming occurs in late spring and summer. Colorful blossoms cover this vine, which may climb up to 20 feet tall. Ideally, clematis foliage should be grown in full sun, while its roots should be kept cool under a mulch. This easy-to-grow vine prefers moist, rich, and porous soil.

COREOPSIS or TICKSEED (Coreopsis grandiflorum) plants produce bright gold flowers from June until frost. The flowers are ideal for cutting and the plants are attractive in flower borders. Coreopsis seeds may be started indoors in late winter and the young plants then transplanted to the spring garden. Coreopsis flourishes in full sun and well-drained soil. This plant is one of the easiest perennials to grow.

DAYLILY (Hemerocallis hybrida) plants are hardy and easy-to-grow. Daylilies are planted in beds or borders, or naturalized in the landscape. Flowers are large and trumpet-shaped; they bloom and die in one day. Daylilies are available in many colors, including red, pink, maroon, lavender, purple, orange, melon, yellow, pastels, and bicolors. The leaves are long and strap-like. Most daylily varieties grow best in full sun.

DRAGON'S BLOOD SEDUM (Sedum spurium coccineum 'Dragon's Blood') is a 4-inch tall succulent plant with numerous stems spreading along the ground. Both the leaves and the blooms of this plant are red, creating an attractive edging or bedding plant. The small, star-shaped flowers are borne in clusters at the ends of the stems. Sedum grows best in full sun and is drought-tolerant.

GYPSOPHILA or BABY'S BREATH (Gypsophila paniculata) grows best in well-drained, well-limed soil in full sun. These mounded plants are long-lived and measure up to 3 feet tall. Although baby's breath may be used in flower beds, it is most often used as a filler in fresh flower arrangements. Tiny white or pink shaded flowers literally cover the gypsophila plant all summer. Baby's breath flowers may also be dried and used in winter bouquets.

HOSTA or PLANTAIN LILY (Hosta sp.) flourishes in shade and is used for edgings, borders, and mass plantings. The plant forms a rosette growth pattern with large glossy foliage in green, blue, golden, or variegated colors--with or without contrasting edges on the leaves. White or lavender blooms form on tall spikes; many varieties are fragrant.

IRIS (Iris x germanica) is also known as bearded iris, or "the poor man's orchid." The German iris grows from rhizomes and is easily propagated by dividing the rhizomes and planting in full sun. The foliage consists of long, sword-shaped, light green leaves. German iris have many blooms on 36-inch-tall stalks during mid- to late spring. Numerous flower colors and color combinations are available, often with a fuzzy yellow "beard" on the lower petals.

PEONY (Paeonia lactiflora) plants are 2 to 3 feet tall bushes with dark green, deeply lobed leaves. Best growth occurs in full sun. Fragrant blooms may be single or double, and up to 8 inches across; they are ideal for cutting. Blossom colors include red, pink, or white. Peonies are extremely long-lived perennials which are common in the spring landscape.

RUDBECKIA or BLACK-EYED SUSAN (Rudbeckia fulgida) plants are long-lived and require minimum care. They grow about 24 inches tall in either sun or light shade. Bright gold 5-inch diameter flowers with bronze-black central cones appear in August and September. These long-living flowers are ideal for arrangements, although Rudbeckia is especially attractive in the naturalized landscape.

SHASTA DAISY (Chrysanthemum superbum) plants are about 30 inches tall. Shasta daisy seeds may be sown directly into the flower garden or may be started indoors and transplanted in the spring to a sunny spot. White flowers (up to 6 inches in diameter) with yellow centers are produced through the summer. The long-stemmed blossoms are long-lasting cut flowers for arrangements. Shastas are low maintenance plants for borders or for naturalization.

Summary

It is necessary to be able to identify floriculture plants in order to provide the optimal cultural care for them. Information has been presented on 98 plants that are important to the Missouri floriculture industry. For identification and classification purposes, these important plants are categorized as follows: bedding plants, house plants, flowering container-grown plants, plants grown for cut flowers/foliage, and perennial plants.

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Plant Propagation

Plant propagation is the controlled reproduction of plants. There are two kinds of plant propagation: sexual and asexual. Sexual plant propagation uses seeds for producing new plants. Asexual plant propagation is the reproduction of plants using a vegetative part of the plant by means of layering, division, cuttings, grafting, budding, or tissue culture (micropropagation).

Germination Requirements for Seeds

Seeds must be placed in an environment that will enable them to germinate and grow. The seeds must have a good germination medium, moisture, favorable temperature, oxygen, and in certain species the presence or absence of light. Seed germination also depends on the selection of quality seed that is viable. A viable seed has the ability to germinate and grow. Some seeds require special treatment to overcome dormancy before the seed can germinate.

The germination medium used for starting seeds should be loose, well-drained, fine-textured, and sterile. Prepared mixes are available commercially, such as Jiffy Mix®, Redi-Earth®, and Pro-Mix®. Some typical germination media that can be mixed are peat-vermiculite-perlite in a 2:1:1 ratio, peat-vermiculite in a 1:1 ratio, vermiculite, and milled sphagnum moss.

Germination begins when the seed absorbs water from the germination medium. The germination medium should be moist. After the seeds are sown, they should be watered gently with a fine mist. The flat should be covered with plastic or placed in a propagation bed; it should not require more water until germination occurs. (Note: Do not set covered flat in direct sunlight, excessive heat will build up.)

Most seeds will germinate when the germination medium temperature is between 68°-86°F (20°-30°C). All seeds do not germinate at the same temperature. Some seeds require cool temperatures, while other seeds need warm temperatures. Heating cables can be used to control germination medium temperature in a shaded area, which should remain as constant as possible during germination.

Seeds require oxygen for respiration. As seeds germinate, the demand for oxygen increases. The germination medium and water supply should allow for adequate air movement. Some seeds require light in order to germinate. If light is required to germinate, the seed should not be covered with germination medium. Some seeds germinate best in the dark. Seeds requiring darkness should be covered with medium or placed in a darkened area. Some seeds will require special treatment to overcome dormancy before they are able to germinate. Seed dormancy will be discussed later in this lesson.

Selection of quality seed from a reliable dealer is important for germination. Good quality seed will be viable and free of insects, diseases, weed seeds, and broken seeds.

Steps in Seed Germination of a Dicot

The steps in seed germination of a dicot include the following.

1. Seed swells as moisture is absorbed.
2. The seed coat splits.
3. The radicle emerges and grows down.
4. The hypocotyl elongates, forms an arch, and pulls the cotyledon upward.
5. When the hypocotyl reaches light, elongation ceases; the hypocotyl straightens up and pulls the cotyledons out of the soil.
6. The cotyledons open up, turn green, and provide food until the true leaves develop.
7. The first true leaves unroll or unfold from the epicotyl, exposing the growth bud; the plant begins to grow.
8. The cotyledons die, dry up, and fall off.

Steps in Seed Germination of a Monocot

Seed germination of a monocot is slightly different than germination for a dicot.

1. Seed swells as moisture is absorbed.
2. Seed coat ruptures.
3. Radicle grows down.
4. First internode and epicotyl grow up.
5. After the epicotyl emerges, new leaves form and food production starts.
6. The new root system grows just beneath the soil, above the first internode.

Overcoming Seed Dormancy

Dormancy is a resting stage of the seed that prevents the seed from germinating until environmental conditions are favorable. Read the seed packet label to determine if a seed is dormant. Some seeds are dormant because of extremely hard seed coats. Seeds with very hard seed coats must be scarified, or scratched, before they can overcome the dormancy. Scarification can be done by rubbing the seed over coarse sandpaper, making a nick in the seed coat, or soaking the seed a few minutes in sulfuric acid. Scarification allows moisture to penetrate the seed coat and germination to take place. Sweet pea seeds require scarification before sowing to facilitate germination.

Some seeds require 12-14 weeks of exposure to cold (40°F [4°C] or below), moist conditions before dormancy can be overcome. This is called stratification. The seeds of vinca germinate better if placed in a freezer for a few days before planting.

Steps in Sowing and Watering Seeds in a Seed Flat

1. Fill the container up to 3/4 inch from the top with moist germination mixture. Make sure the container has adequate drainage.
2. Level and gently firm the germination medium. A clean, small board may be used for leveling and firming the germination medium.
3. Using a narrow board or label, make shallow rows 1 to 2 inches apart in the flat. Different seeds can be sown in the same container if planted in rows.
4. Space the seeds uniformly and thinly in rows. Many small round seeds may be spaced in the rows by gently tapping the seed package over the rows. Label each row or flat with plant type, variety, and date of planting.
5. Cover the seeds with dry germination medium, vermiculite, or milled sphagnum moss. The depth of covering depends on the size of the seeds. Very small seeds do not need to be covered. A general rule of thumb to follow is to cover the seed no deeper than twice its diameter.
6. Moisten the surface with a fine mist or place the container in a shallow pan of warm water and let the seed flat take up water from below until the surface is moist, then remove from the water.
7. Cover the flat or container with clear plastic or glass. This causes the moisture to be retained. Uncovered flats may be placed in a propagation bed. No additional watering should be needed until after the seeds have germinated.
8. Place the container in a warm location for best germination. Generally a temperature range from 65°-75°F (18°-24°C) is best for germination. Check proper germination temperatures for best results.
9. Watch daily for germination. Also, check for lack of water, excess water, or disease.

Seedling Care

After seeds have germinated, the cover should be removed. The container should be moved to a location that receives bright light. The growing temperature is usually 10°F cooler than the germination temperature. Seedlings die quickly if allowed to dry out. Flats should be kept moist at all times, but not soggy. Allow drying between waterings, but do not allow seedlings to wilt at any time.

Seedlings grown in artificial media will need prompt and regular fertilization. Apply a water soluble fertilizer at about one-fourth the recommended strength a few days after seedlings have germinated. Then fertilize twice a week with the diluted solution (about 150 ppm nitrogen). Young seedlings are easily damaged by too much fertilizer.

When to Transplant Seedlings

Seedlings should be transplanted as soon as they have developed at least one set of true leaves that are large enough to handle. If seedlings are not transplanted promptly, they may become overcrowded and spindly, producing a poor quality plant.

How to Transplant Seedlings

To transplant seedlings, carefully dig up the small plants with a knife, spatula, or label. To avoid excess loss of seedlings, dig up only small groups of seedlings at a time. Exposing the roots to air causes them to dry out quickly. Next, gently separate the seedlings and pick out individual plants to be transplanted. If seedlings are difficult to separate, gently ease them apart into smaller groups that are easier to separate into individual plants. Avoid tearing roots. When handling seedlings, hold them by their leaves, as their stems are easily crushed or broken.

Seedlings should be transplanted into individual pots or packs. The container should be filled with a commercial mix or a home-mix (e.g., 2:1:1 ratio of peat:vermiculite:perlite). The growing medium should be moist. Poke a hole in the center of the growing medium with a dibble or pencil. Insert seedlings to a depth slightly deeper than they were growing in the seedling flat. After planting, lightly firm the soil and water gently with warm water. This will settle the growing medium around the roots.

The newly transplanted seedlings should be placed in the shade or covered with a shade cloth for a few days. Continue to water and fertilize as recommended for the plant species.

Disease Control Measures

To guard against plant diseases, be sure to use a soilless medium or sterilized soil and sterilized containers. The soil medium mixtures can be sterilized by heating to 180°F (82°C) for 30 minutes using steam or electricity. Chemicals can also be used to sterilize soil. Commercial mixtures do not require sterilization. Containers and implements should be disinfected in a solution of one part chlorine bleach and ten parts water or a commercial disinfectant such as Physan 20®. Allow all items to dry before filling with soil.

Watch seedlings closely for development of any plant diseases and control promptly if any disease develops.

Damping-off is a fungal disease that causes seedlings to die. If only a few seedlings are attacked, dig out and discard infected plants and soil. If the infection is widespread, drench the entire soil area with a fungicide to prevent further spreading of the disease. Improve air circulation and allow the soil to dry out slightly between waterings.

Summary

Some seeds will not germinate until certain environmental conditions are met. After germinating in the seed flat, the seedlings are usually transplanted into larger individual containers for growing.

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Lesson 14: Asexual Plant Propagation

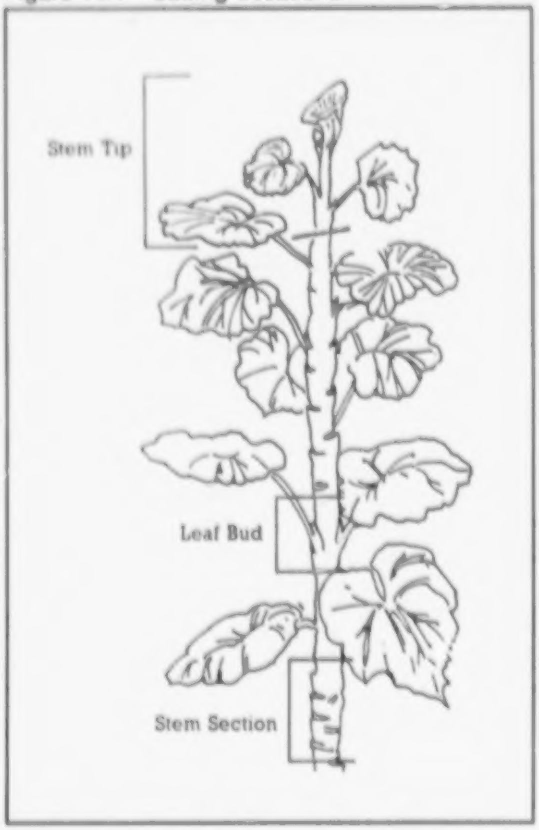
To successfully grow plants, it is important to understand the principles and techniques of asexual plant propagation. This lesson discusses propagation of plants by cuttings, division, layering, budding, grafting, and tissue culture propagation.

Methods of Asexual Plant Propagation

Plants propagated by asexual methods will have the same genetic makeup as the parent plant, because asexual methods take a portion of a single plant to produce new plants. Cuttings, division, layering, grafting, budding, and tissue culture, a relatively new method, are asexual propagation methods used by commercial growers.

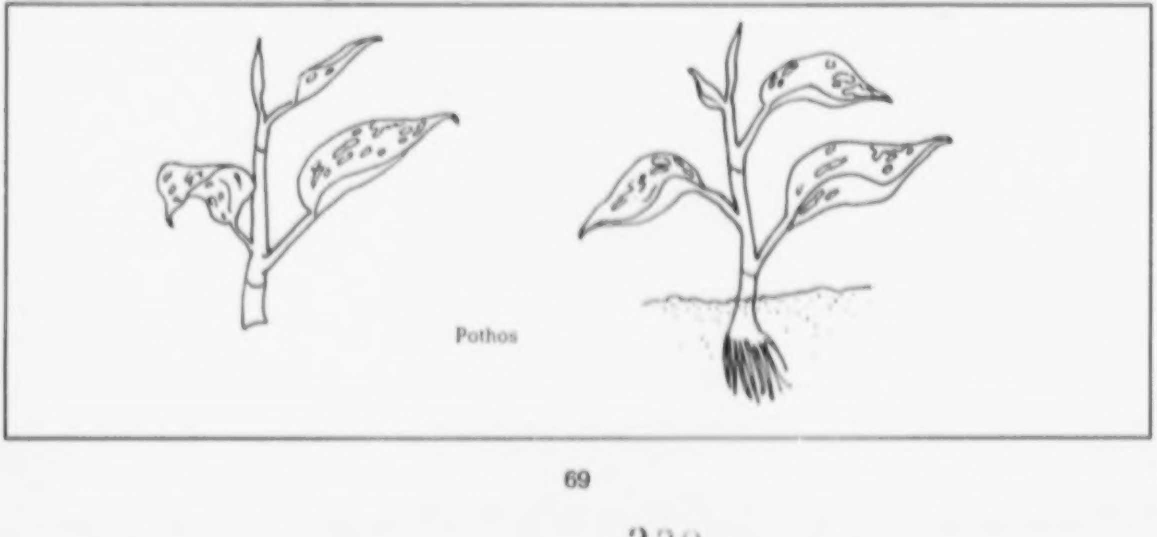
Cuttings - Cuttings are plant pieces that are "cut" from the parent plant and rooted to form new plants. Cuttings may be taken from stems, leaves, and roots. There are four types of cuttings: stem tip cuttings, leaf cuttings, leaf and bud cuttings, and stem section cuttings. Figure 14.1 illustrates the location of stem tip, leaf bud, and stem section cuttings on a typical plant.

Figure 14.1 - Cutting Locations



Although fingers may be used to remove the cutting, a sharp knife is usually used to make a stem tip cutting. Remove a two- to four-inch terminal stem tip section. The cutting should be removed just above a node. Leaves should be removed from the lower third to half of the cutting. Treat the end of the cutting with a rooting hormone; then place it in a container with a rooting medium. Rooting medium is usually more highly aerated than growing medium. In addition, it is important that rooting medium be totally inert or sterile to avoid diseases. Oasis Rootcubes®, which are usually 1 1/2 inches in diameter, are composed of a synthetic foam-like material, usually brown or green in color. This soilless, sterile rooting media has the correct pH for

Figure 14.2 - Stem Tip Cutting



cuttings and is well aerated. Cuttings will root quicker if placed in an area with high humidity and bottom heat (75°-85°F or 24°-29°C). Figure 14.2 illustrates a pothos cutting before and after root and plant growth.

Plants may be started from cuttings taken from the entire leaf, the leaf and petiole, or a section of a leaf. Figure 14.3 illustrates where plant development occurs in leaf cuttings. A leaf or a section of a leaf is removed from the parent plant, treated with a rooting hormone, and placed upright into the rooting medium. Another leaf cutting is done by cutting several veins in a broad, thick leaf (e.g., Rex Begonia) and pinning the leaf to the medium so that the wounded veins are in contact with the rooting medium. New plants will form where the veins have been cut. Still another type of leaf cutting uses the entire leaf and petiole. One or more plants will form at the base of the petiole.

Figure 14.3 - Leaf Cuttings

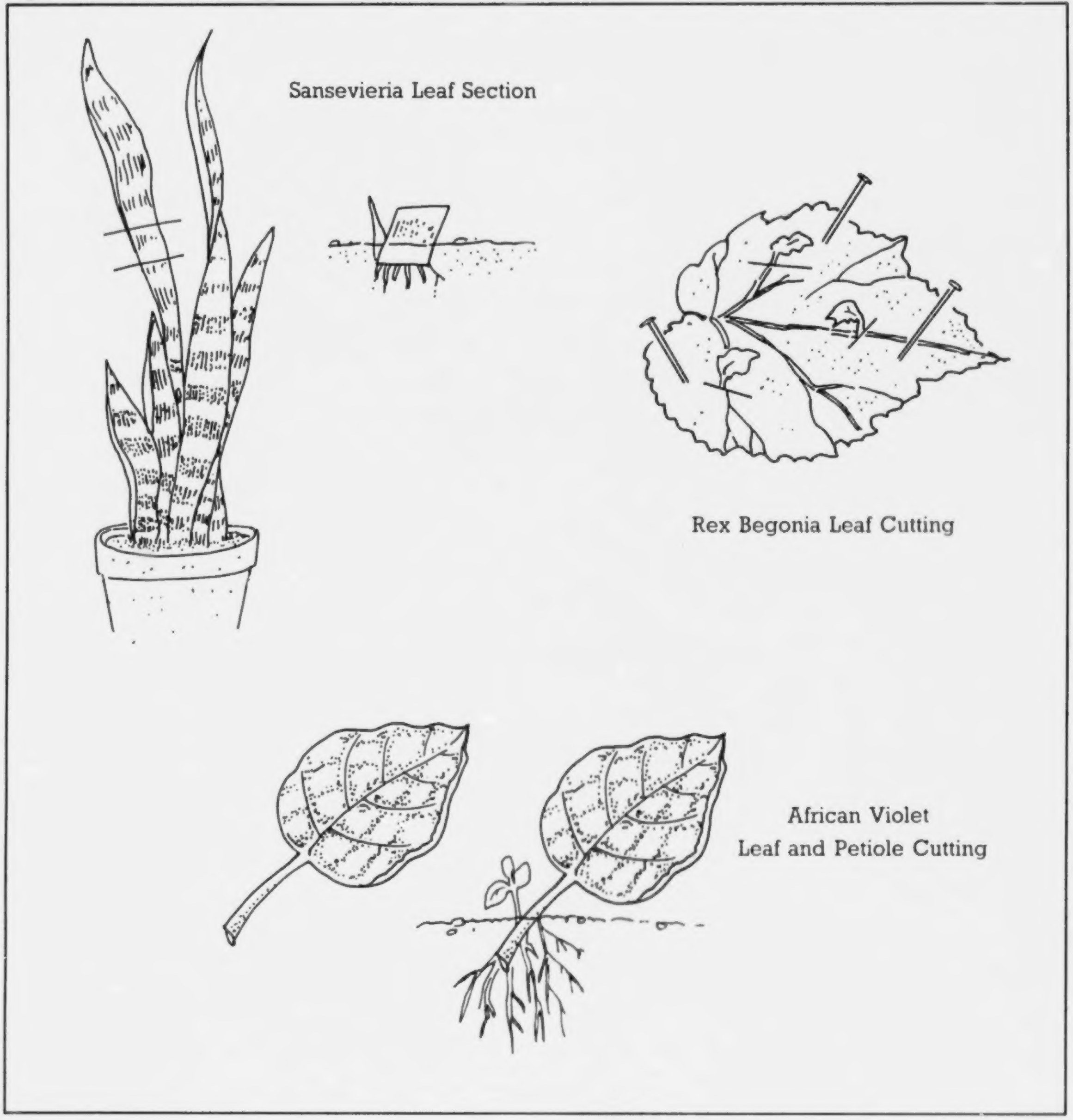
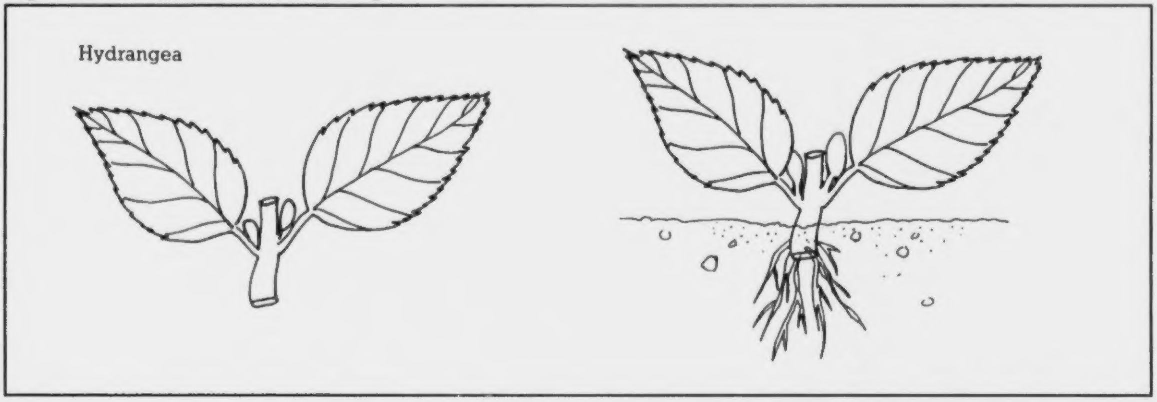


Figure 14.4 - Leaf and Bud Cutting



A leaf and bud cutting consists of the leaf blade, petiole, and a small section of the stem with the attached axillary bud. As illustrated in Figure 14.4, plant growth begins at the bud. Each section that contains a node can be used as a cutting. The cutting should be placed with the bud right at or slightly above the surface of the rooting medium. The leaf can be placed in an upright or horizontal position.

A few plants are propagated by using stem sections. A one- or two-inch section from the stem containing at least one dormant bud is placed in the rooting medium horizontally. The stem section should be nearly covered. Roots form on the cut portions of the stem touching the rooting medium. This process in turn causes the bud to start growing. See Figure 14.5.

Division - Division is a way to propagate plants by separating clumps of plants into small groups, each having roots, stems, and leaves or the potential to develop these parts. Division is the easiest way of propagating plants that produce offsets or basal shoots or that produce a multiple crown (e.g., Boston fern). See Figure 14.6.

Layering - Layering is the method of rooting a new plant while the stem is still attached to the parent plant. Types of layering include simple, tip, compound, mound, trench, and air. Simple and air layering are the most frequently used types in the greenhouse. Air layering is the method most suited for propagating foliage plants.

Figure 14.5 - Stem Cutting

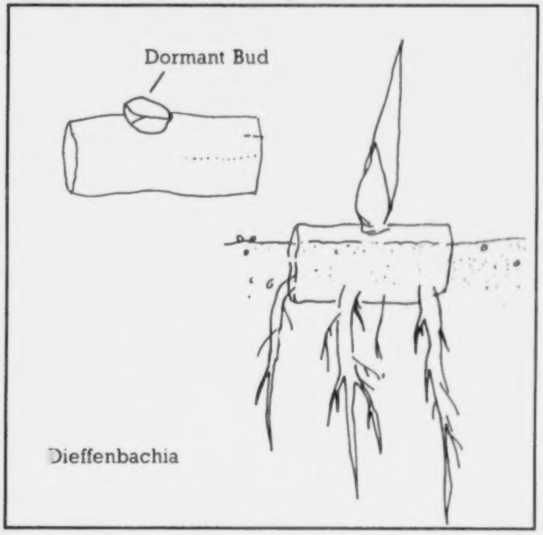
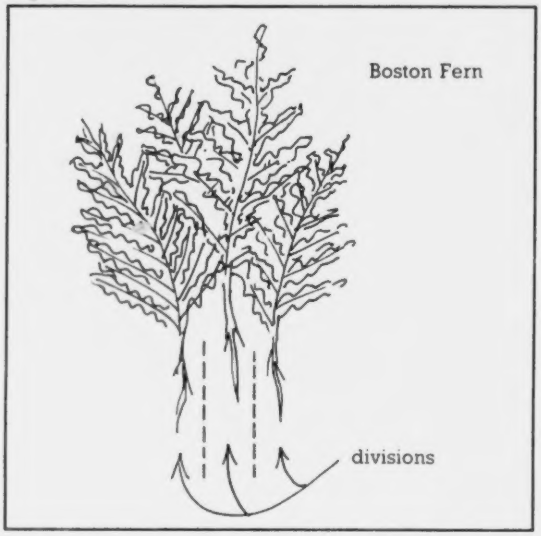
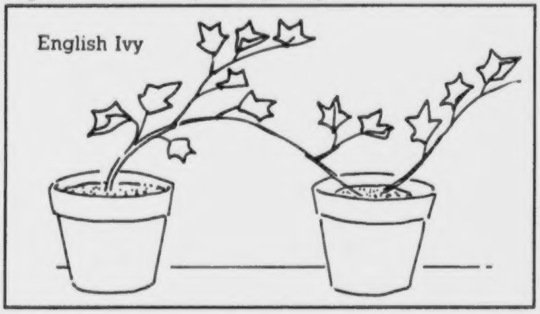


Figure 14.6 - Division



Simple layering is a method in which a portion of the stem is wounded and buried, leaving the tip exposed. See Figure 14.7. English Ivy and similar foliage plants can be rooted easily by simple layering.

Figure 14.7 - Simple Layering



Tip layering is the method in which the tip of the stem is wounded, treated with a rooting hormone, and buried. Tip layering is similar to simple layering, but the terminal tip of the plant remains buried.

Compound layering is also known as serpentine layering. A stem is alternately covered and exposed, allowing the stem to root in more than one location. The section of the stem that is covered should be wounded and treated with a rooting hormone. The section of the stem that is exposed to the air should have a bud where a new shoot will develop.

Mound layering is used on woody plants such as roses and fruit trees. The stem of the plant is cut back during the dormant season and covered with a mound of soil. New shoots form on the stems that will develop roots later.

Trench layering is another method used to propagate woody plants such as roses, spirea, and rhododendron. The entire plant is bent over and buried except for the terminal tip. The stem is wounded and treated with rooting hormones at intervals along the stem to encourage rooting. When the new roots and shoots have developed enough, the stem is separated into individual plants. Tip, compound, mound, and trench layering are seldom used on greenhouse crops.

Air layering is a method used for propagating some plants by inducing rooting along the above-ground section of the stem. See Figure 14.8. Ficus, Philodendron, and Dieffenbachia are some plants that are easily rooted by air layering.

Leaves are removed from several inches around the point on the stem where the layering is to be done. An upward, slanting cut should be made about one-third through the stem on alternate sides. Then the wound is dusted with a rooting hormone. A sterile wooden toothpick or match-stick is used to hold the cut open. Another method of wounding the plant would be to remove the epidermis from a section of the stem. A handful of moist sphagnum moss is placed around the wound. The ball of sphagnum moss should be covered with clear plastic and held in place with string, ties, or electrical tape. Many growers place a piece of aluminum foil over the plastic. The foil reflects heat and prevents light from reaching the root ball.

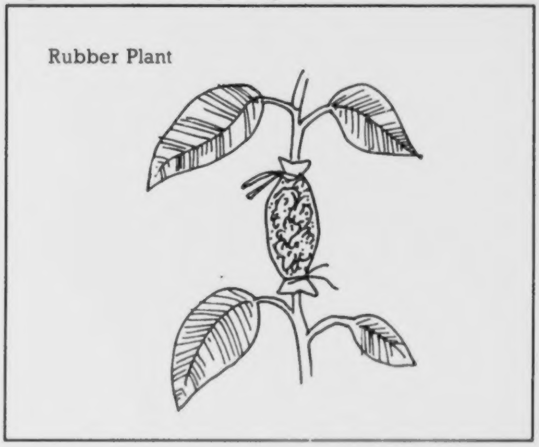
The ball of sphagnum moss should be checked periodically to make sure it is moist and to see if roots have formed. It may take a month or more before rooting occurs. Once roots are visible, the new plant is cut away from the parent plant and potted.

Grafting - Grafting is a method of propagating plants by inserting buds, twigs, or shoots from one plant onto the stems of another plant. Grafting is used mainly to produce fruit trees. Grafting has little, if any, use on greenhouse crops.

Budding - Budding is a special form of grafting that uses a single bud which is inserted into the bark of another variety. Budding is used on fruit trees, nut trees, and rose plants. Commercial greenhouse growers usually purchase rose plants that have already been budded.

Tissue culture or micropropagation - Tissue culture is a relatively new propagation technique in which

Figure 14.8 - Air Layering



a single cell or a few cells are taken usually from the meristematic tissue of a plant to produce a new plant. The small piece of plant tissue is placed on a germ-free condition into a specially prepared growing medium in test tubes. Chemicals and growth regulators are used to control the root and shoot growth. When the plants are large enough to handle, they are transplanted into another growing medium, where they are grown in controlled environment chambers for several weeks. The plants are then transplanted into individual pots and are ready to be placed in a greenhouse.

Using Rooting Hormones

Rooting hormones are used to increase the percentage of cuttings that root. These auxin-type growth regulators cause cuttings to root more quickly and consistently. Two synthetic rooting hormones that stimulate root development are indolebutyric acid (IBA) and naphthaleneacetic acid (NAA).

Applying Rooting Hormones

The recommended method of applying rooting hormones is dusting. Rooting hormones come in powder or solution forms. By applying rooting hormones in a powder form with a squeeze bulb duster, only a small amount is applied to the base of the cutting. Applying too much rooting powder may cause the stem to rot. In the absence of a squeeze bulb duster, rooting hormone may be applied by dipping the cut surface of the plant tissue into the rooting powder and shaking off any excess. It should be noted that if cuttings are dipped in the rooting powder (or solution), disease organisms can be spread from diseased cuttings to healthy cuttings. If a solution of rooting hormone is used, the cuttings should be dipped in a strong solution for a short period of time.

Never dip cuttings into the original rooting hormone container. Always pour the amount of rooting hormone needed to treat the cuttings at any one time into a sterile container. Any rooting hormone that has been applied to plant tissue by dipping should be discarded after each use. A fresh supply of rooting hormone should be purchased each year.

Tools Used for Plant Propagation

The most important tool used for plant propagation is a sharp knife. A knife is used to remove or divide plant material from the parent plant. A knife is also used to make wounds in the plant material. A dibble stick is used to make holes in the rooting medium. A squeeze bulb duster can be used to apply rooting hormones.

Sanitation

Sanitation is important for successful propagation. Knives must be kept clean and sterile when taking cuttings to help prevent the spread of disease. Knives should be disinfected with rubbing alcohol or a bleach solution after making each cut. Additionally, cuttings should be placed in sterile plastic bags or in sterile flats lined with newspaper to be moved to the rooting area. Cuttings should never be laid on the ground or on benches. The rooting medium should be sterilized between each use. Remove and throw away any plant debris from the benches and rooting flats.

Use of Labels

It is important to use labels to keep accurate track of information on all plants. Labels should contain the following information: plant name, variety, date propagated, and any special treatment given. The information should be printed clearly with a pencil or waterproof marking pen. Ballpoint ink should not be used because it fades when the plants are watered.

Summary

Herbaceous cuttings, division, and simple and air layering are the most commonly used asexual propagation methods in the commercial greenhouse. It is essential for the greenhouse worker to be able to produce plants by these methods. Using rooting hormones and following good sanitation procedures ensures a good start for the plants. It is important to record the plant name, variety, date propagated, and any special treatment for the plant on the label.

Credits

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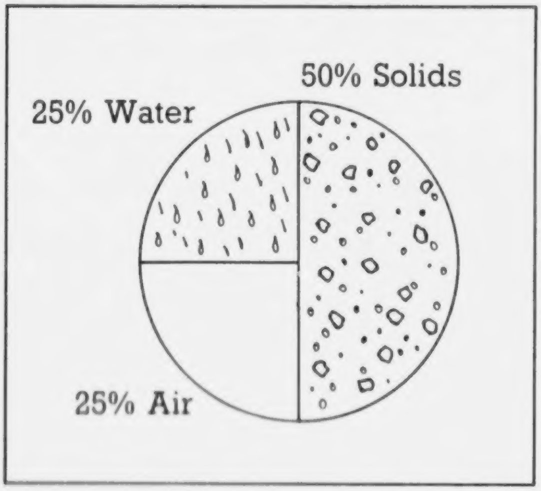
Greenhouse-produced floriculture crops are grown in what is referred to as a growing medium (singular) or growing media (plural). Soil-based media were used to grow plants in early greenhouses and their use continues to a certain extent today. The current trend in the floriculture industry is to grow crops in soilless media (e.g., blends of peat moss, vermiculite, perlite, processed bark). Commercially-prepared soilless mixes are commonly available and ready-to-use from the bag.

Since many types of growing media are available for use in the commercial greenhouse, it is important to understand the functions and characteristics of the growing medium and its influence upon plant development. A good growing medium is required for good plant root growth and good plant root growth is required for good stem, foliage, and flower development.

Ideal Growing Medium

Regardless of the type of growing medium used, it must fulfill the following functions: support or anchor the plant in place so that it does not fall over; hold essential plant nutrients; retain sufficient water; and hold sufficient oxygen, especially for respiration of roots. Plant nutrients, water, and oxygen are required for normal plant growth and development. The ideal growing medium has several characteristics. It should be able to retain sufficient moisture for good plant growth. Yet the medium should have sufficient porosity to allow excess water to drain quickly and permit adequate aeration. Consequently, the medium should be loose and porous. Figure 15.1 illustrates the porisity of the ideal growing medium.

Figure 15.1 - Porosity of the Ideal Growing Medium

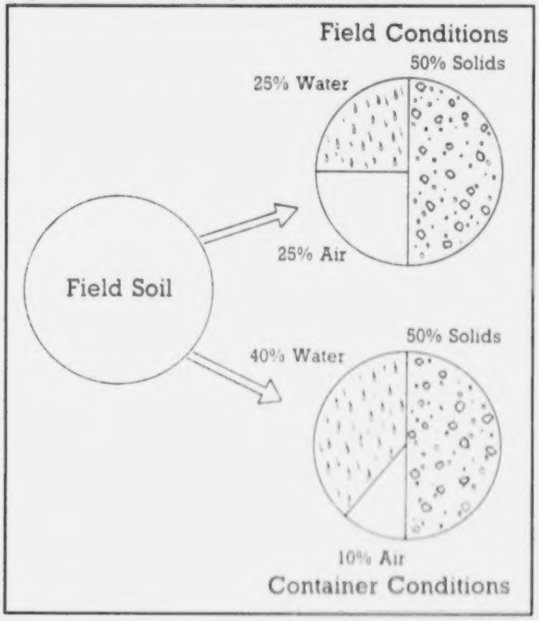


Although a function of the growing medium is to hold nutrients, the ideal growing medium initially should be low in nutrients, since it is easier to add the required mineral elements than it is to remove excessive amounts, which can be toxic to plants. The pH or acidity level of the medium should suit each individual floral crop. The volume of the medium must stay constant. The growing medium must be dense to firmly hold the plant material in place, even after watering. The medium must be free of unwanted seeds or weeds, insects, nematodes, and all other disease-causing organisms; in other words, the medium must be pathogen-free. The medium must be inert or nonreactive.

Soil-Based Growing Medium

In early greenhouses soil was the growing medium of choice primarily because it was the only material available. In modern greenhouses, unamended soil is rarely if ever used as a growing medium. Soil direct from the field lacks the proper balance between air and water retention when placed in a pot. See Figure 15.2. Therefore soil needs to be amended with materials that will make it lighter and better drained. Refer to Figure 15.1 for the ideal porosity of a growing medium. Amendments such as peat moss, processed bark, sand, vermiculite, and perlite, are commonly used to improve soil as a growing medium.

Figure 15.2 - Porosity of Field Soil



The amount of amending required by a soil to render it suitable for container-grown crops depends largely on the soil's original texture. Soil texture refers to the percent clay, silt, and sand particles contained in the soil. The greater the percentage of fine particles (clay and silt) the more course amendments are needed to give the medium the necessary porosity. The best horticultural soil texture is a blend of clay, silt, and sand. Such a blend is referred to as a loam soil.

A typical soil-based medium might contain (by volume) 60 percent loam-type soil, 20 percent sphagnum peat moss and 20 percent perlite. Other ratios using these or other amendments could be used to create lighter (more porous) or heavier (less porous) mixtures.

Soil-based mixes are heavy, therefore, top-heavy plants are less likely to fall over and require less frequent watering. But because they are heavy, their use increases shipping costs. Soil mixes have variable nutrient levels even though many of the trace elements are in adequate supply. Since the soil base will vary from one mix to the next, it is hard to reproduce a soil-based mix consistently. Also, the soil in the mix may contain pesticides, weed seeds, insects, or disease-causing organisms thus necessitating pasteurization.

Soilless Growing Medium

Soilless growing media contain no naturally-occurring soil. Soilless growing media are basically mixtures of sphagnum peat moss or wood products such as processed bark and amendment blended in various ratios. Perlite, vermiculite, sand, and calcined clay are examples of amendments.

A soilless growing medium has several characteristics. It is lightweight, making it cheaper to ship. It is low in nutrients, therefore fertilizers are required on a regular basis. Soilless mixes are essentially inert or nonreactive, thus eliminating the need for pasteurization. Since they drain well, it is harder to overwater plants, thereby decreasing the chance of root rot diseases. A soilless growing medium is also porous, loose, and open. Refer to Figure 15.1 for the porosity of the ideal growing medium. It is hard to wet initially and requires frequent watering.

In addition, soilless media have a fairly standard and fixed composition making it easier to follow the same procedures to produce a quality crop. They may be purchased in ready-to-use bags or custom-mixed in the greenhouse. The two main types of soilless blends are peat-lite mixes and mixes containing processed bark along with other amendments. Typical formulas for various uses are shown in Table 15.1.

Growing Media Amendments

An amendment refers to any material that is added to a growing medium to improve its ability to support plant growth. Amendments may either be organic (coming from living sources) or inorganic (coming from nonliving or mineral sources) in nature. The most commonly used organic amendment is partially decomposed sphagnum peat moss.

Sphagnum peat moss, as well as the other organic amendments, serve to improve the growing medium in the following ways: increase water holding capacity; decrease compaction and increase pore space, thus increasing the amount of air and water drainage; improve structure of soil-based media by causing soil particles to clump into aggregates; and increase cation exchange capacity (ability to hold mineral nutrients for eventual uptake by roots) of the medium. It is important that organic materials be slow to decompose and contain large particles or have coarse texture. Sphagnum peat moss, which is fibrous and brown in color, is preferred. Other types of peat moss (e.g., humus peat or reed-sedge peat) rapidly decompose--too rapidly for horticultural purposes. Additionally, they are poorly aerated and increase the chance of overwatering.

Sphagnum peat moss - Sphagnum peat moss is available in 0.2 cubic foot bags up to 7 cubic foot compressed bales. Be sure to purchase the horticultural grade of peat. Before incorporation into a growing medium, peat must be moistened. Dry peat is difficult to wet, but once thoroughly moistened, it will absorb water--up to 20 times its original weight. This water is available for uptake by plant root hairs. As a general rule, peat does not contain pests, weed seeds, or disease-causing organisms. As peat decomposes, it slowly releases mineral nutrients into the soil. However, peat is not a sufficient source of nutrients, so fertilizers must be applied. The pH of peat is usually strongly acidic; ground lime-stone may have to be added to the soil blend in order to raise the pH to 5.5-6.5 which is optimum for growing most greenhouse crops. Sphagnum peat moss is lightweight when dry, as well as convenient to handle and store.

Table 15.1 - Components for Soilless Mixes

To prepare this mix:	Incorporate these ingredients: Sphagnum peat moss (cu yd)*	Hort. vermiculite (cu yd)	Hort. perlite (cu yd)	Douglas fir bark, fine ground (cu yd)	Ground dolomitic limestone (lb)	Treble superphosphate (lb)	Calcium or potassium nitrate (lb)	Trace elements	Iron sulfate (oz)	10-10-10 (lb)	Osmocote 14-14-14 (lb)	Magamp 7-40-6 (lb)	Wetting agent (oz)
1. Mix A for seedlings/bedding plants	0.5	0.5			5	0.5-1.0	1	See note†					3
2. Mix A – Slow release fertilizer for potted plants (except poinsettias & lilies)	0.5	0.5			5	0.5-1.0	1 potassium nitrate	See note†			5 plus 5		3
3. Mix A for poinsettias (liquid feed)	0.5	0.5			5	4	1	See note†					3
4. Mix B – Slow release fertilizer for potted plants (except poinsettias & lilies)	0.5		0.5		5	0.5-1.0	1.5 potassium nitrate	See note†			7.5 plus 7.5		3
5. Mix C for lilies	0.5	0.25	0.25		10		1.5	See note†					3
6. Foliage plant mix‡	0.5	0.25	0.25		8	1.0	1.0 potassium nitrate	See note†	0.75	2.5			3
7. Epiphytic mix‡	0.33		0.33	0.33	7	2.0	1.0 potassium nitrate	See note†	0.50	2.5			3

* One cu yd = 27 cu ft. However, 15 to 20 percent shrinkage occurs in mixing; and for 1 full yd, use 2 additional bu of peat moss and 2 additional bu of perlite or vermiculite.

† Trace elements. Use 3 oz of FTE 503; *or* 4 oz of FTE 555; *or* 4 lbs of ESMIGRAN; *or* 4 lbs of PERK per cu yd of mix.

‡ Developed by R. C. Mott, formerly of the L. H. Bailey Hortorium, Cornell University.

Credit: Cornell Recommendations for Commercial Floriculture Crops, Part I: Cultural Practices and Production Programs. Cornell University, 1979.

Processed bark - Processed bark is another common organic amendment added to soil. The particle size of the bark pieces should be 1/4 inch or less in diameter. Some types of bark often used in floriculture are pine, fir, and cedar. Bark particles may be difficult to wet initially because of the natural resins contained in the bark. When using bark in a soil mix, it should be supplemented with nitrogen fertilizer. Softwood bark is preferred because it decomposes slower than hardwood bark.

Some inorganic or mineral amendments to add to soil include the following: calcined clay, perlite, vermiculite, and sand. All of these mineral amendments serve to improve soil aeration, as well as to improve soil water drainage.

Calcined clay - Calcined clay is special clay that has been heated to 1300°F to form heavy particles, which are porous and able to hold a large amount of water. In addition, calcined clay has a high cation exchange capacity, enhances good soil structure, and adds bulk to the medium. Calcined clay is available in 50 pound bags.

Perlite - Perlite is white volcanic rock that "pops" after being fired at 1600°F. These white particles are easily seen in the soil, so proper blending is assured. Although a perlite particle can hold water up to four times its own weight, it has no cation exchange capacity. This material significantly improves soil aeration, thus giving a growing medium better drainage. Perlite has a neutral pH. Horticultural grade (coarse or fine) perlite is available in easy-to-store four cubic foot bags. In addition, perlite is durable, lightweight, sterile, clean, and easily handled when wet. Perlite is frequently used to propagate cuttings and to start seeds.

Sand - Readily-available and inexpensive, sand is a common soil amendment. With its large particle size, sand has great porosity with good aeration and good water drainage. Sand must be pasteurized or heated to destroy disease-causing organisms. Sand adds weight and physical support to the growing medium to prevent the plant from toppling over. Sand has little water-holding capacity or cation exchange capacity. It is essentially inert (i.e., contains no nutrients).

Vermiculite - Vermiculite is lightweight expanded mica that has been fired at 1400°F. Along with containing significant amounts of the essential nutrients magnesium, calcium, and potassium, vermiculite has a high cation exchange capacity. Vermiculite is able to hold a great deal of water and air. The pH may vary from a neutral 7.0 to a very alkaline 10.0, depending upon the source of mica. Generally available in four and six cubic foot bags, vermiculite grades 2, 3, and 4 are recommended for horticultural purposes. The No. 3 grade is most commonly used. This amendment is frequently used for propagating cuttings and as a seed germinating medium. Do not use vermiculite intended for insulation purposes. Some disadvantages of vermiculite are that it compresses easily and crumbles easily.

Summary

Conditions in the growing medium largely determine a plant's root system status, which in turn determines growth and development of the entire plant. In general, the medium serves to anchor the plant in place, as well as to hold sufficient water, oxygen, and nutrients for eventual uptake by plant roots. Growing media may contain soil or may be soilless. In addition, various amendments are frequently added to growing medium in order to improve its quality. Hence, many types of growing media are used in commercial greenhouses.

Credits

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Many different types of containers are available for plant production. Since the composition and size of the container can affect plant growth and quality, it is important to be familiar with different containers used in greenhouse production in order to choose the best container for the plant.

Growing Container Composition

A wide variety of materials is used for making plant containers. Today, most commercial growers use containers made of clay or plastic. There are several other materials that may be used, but are seldom found in the commercial greenhouse. These less commonly used container materials include peat moss, thin fiberboard/composition material, wood veneer, ceramic or glazed clay, concrete, glass, fiberglass, and stone. Just about anything that can hold a plant and some growing medium may be used as a decorative container.

Advantages and Disadvantages of Clay and Plastic Containers

Clay - The longest-used container material in the world is clay. Stone carvings dating back over 3,500 years depict plants, particularly fruit trees, growing in earthenware containers. Clay containers have been popular for many years with commercial plant producers. The primary advantage of clay is that it "breathes" or is porous; hence, excellent aeration or gas exchange between the environment and the plant root system occurs.

In addition, clay containers drain water readily and therefore prevent overwatering from occurring. Because of this, clay containers are excellent choices for growing those types of plants that are prone to developing root rot. Overwatering is the most common cause of plant death. Since clay pots are heavy, especially after being watered, they are stable on the greenhouse bench and less likely to tip over. Finally, clay containers are long-lasting and may be reused if steam sterilized.

In spite of these advantages, clay containers are currently declining in popularity due to their disadvantages. The main disadvantage of clay containers is that plants in clay pots dry out faster as water constantly evaporates through the porous sides. Thus, plants growing in clay containers require more frequent watering. Over time, an unsightly buildup of fertilizer salts (white residue) appears on the outside of clay containers. A green coating of algae often flourishes on moist clay pots. Most clay pot manufacture's offer to treat pots with a silicon-containing algae inhibitor for a slight extra cost. Clay containers are heavy to lift and to ship, subject to breakage, and relatively more expensive than other containers.

Plastic - Plastic is probably the most widely-used container material in the American floriculture industry today, primarily because it's less expensive than the others. Plastic containers are considered to be sterile when new, and can easily be sterilized with a liquid disinfectant for reuse. Because of its light weight, plastic is easier to ship and handle than other containers. Plastic containers are less likely to maintain a buildup of fertilizer or algae; any residue which does form can be easily removed. These thin-walled containers are available in many shapes (often round or square), sizes, and colors. In addition, most hanging containers or hanging baskets are made of plastic. The main disadvantage of plastic is that it is nonporous, resulting in poor aeration of the plant root system. Waterlogging also occurs unless watering practices are altered or the growing medium is adjusted in porosity. Improperly stored plastic becomes brittle and cracks easily with age.

Peat containers - Peat containers are made from peat moss pressed into thin sheets and then molded into the typical pot shape or even into pellets of compressed peat. Peat containers are made of all natural products, which allow the plant roots to penetrate the walls of the container. Peat containers can be transplanted with the plant, thereby reducing transplant shock to the plant, as well as lessening root damage during transplanting. The main disadvantage of peat pots is that they will only last about two months before they start to crumble. Peat containers should never be allowed to dry out since they are hard to re-wet. If they are allowed to dry out, the roots of the plant will also dry out.

Selecting Containers

The growth habit and the intended market of the plant influence the type of container used. The growth habit of the plant crop being grown (i.e., plant height, width, and shape and its requirements for root space) will determine the optimal choice of container shape. As illustrated in Figure 16.1, shorter and bushier plants look better proportioned if planted in a wider, shorter container; tall plants look better proportioned if grown in a deeper container. Figure 16.2 illustrates the four basic container shapes (i.e., standard pot, azalea pot, rose pot, and bulb pot) used by florists. The width of the pot is measured at the top.

Figure 16.1 - Containers in Proportion with Plants

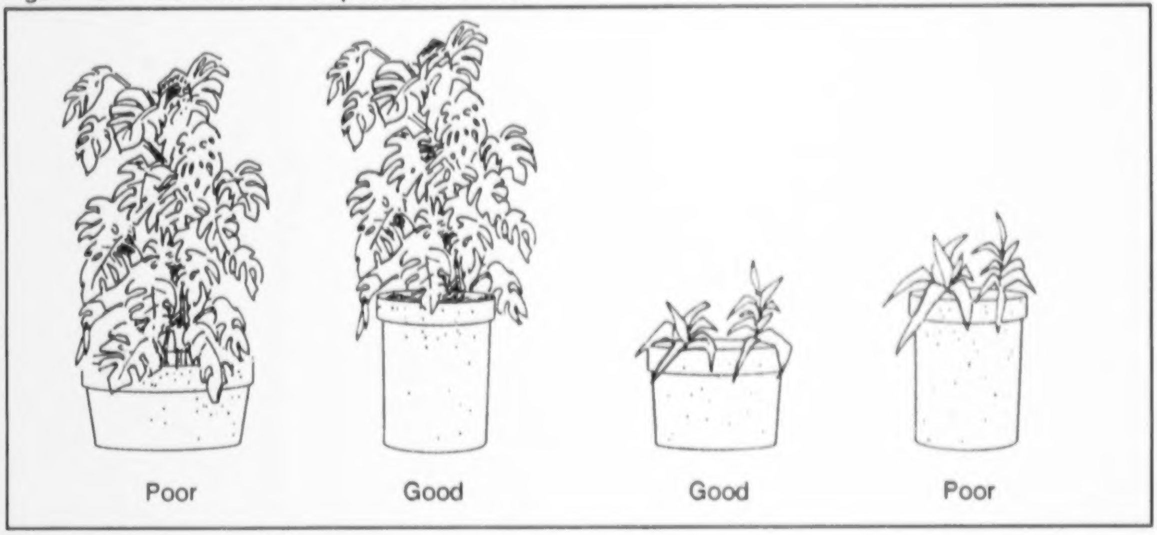
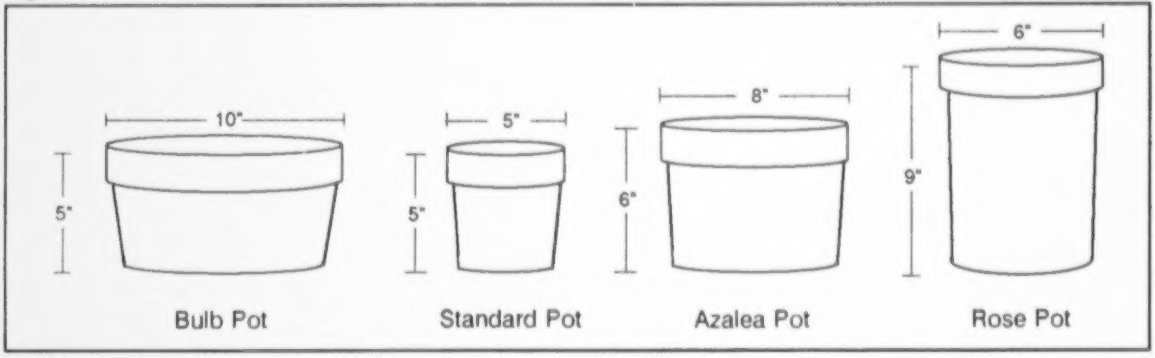


Figure 16.2 - Container Shapes



The intended market can also affect container choice. For example, mass merchandising outlets, such as chain stores, prefer less expensive individual plants. To accommodate this market while at the same time realizing an adequate profit, a greenhouse operator would produce small plants, spaced more closely together on greenhouse benches. Such plants would dictate a smaller, less expensive container such as plastic. Retail florist shops, on the other hand, often demand larger, more expensive plants. These call for larger pots, often made of clay to avoid tipping over due to the large size of the plant.

Standard pot - A standard pot is as tall as it is wide (e.g., 5 inches wide and 5 inches tall). A standard pot is best suited for a plant that is not top-heavy.

Azalea pot - In proportion, the azalea pot is 3/4 as high as it is wide. Flowering plants with heavy, spreading foliage and blooms (e.g., poinsettia or chrysanthemum) are often grown in azalea pots, because the wide base provides stability for the top-heavy plants. An 8-inch azalea pot measures 8 inches across the top and 6 inches deep.

Rose pot - A rose pot is 1.5 times as tall as it is wide. Rose pots are ideal for growing plants (often perennials) with large, deep root systems. A 6-inch rose pot would measure 6 inches across the top and 9 inches deep.

Bulb pot - The bulb pot, sometimes called a bulb pan, is half as tall as it is wide. It is designed for shallow-rooted bulb crops (e.g., hyacinths, daffodils, or tulips). A 10-inch bulb pot measures 10 inches in width and 5 inches in height.

Basic Greenhouse Container Sizes

The floriculturist will chose container size, as well as composition type, based upon the particular plant being grown and the target market or marketing strategy for the greenhouse crop.

Pots - In Missouri, the most commonly grown flowering plants are poinsettias and chrysanthemums. They frequently are grown in 6-inch clay or 6.5-inch plastic azalea pots. However, they may be flowered in 4-inch pots and larger. Geraniums generally are grown in 4-inch clay or 4.5-inch plastic azalea pots, although they may also be planted in many other container sizes. Blooming and foliage plants are commonly grown in 5-, 7-, or 8-inch standard and azalea pots.

Perennial plants, such as roses, are grown in rose pots ranging in size from 6 inches to 3 gallon. Large indoor foliage plants are often sold in even larger containers containing 5 to 7 gallons of growing medium.

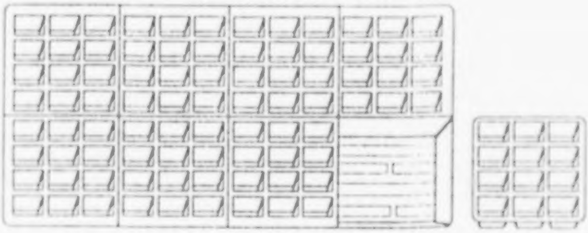
Hanging baskets - The most common hanging basket sizes are 8- and 10-inch plastic. Trailing foliage plants and spring annuals are frequently sold in hanging baskets.

Bedding plant packs - Bedding plant packs contain varying numbers of cells, most often ranging from 1 to 12 individual cells per unit, and 6 to 18 units per sheet. Codes are used to designate the number of units per sheet and cells per unit. Figure 16.3 illustrates the "812" pack which has eight units per sheet, each unit having 12 individual cells. Therefore, there would be space for 96 individual plants in a sheet of "812" bedding plant packs. An "804" bedding plant pack, which contains 8 four-cell units, is also illustrated in Figure 16.3.

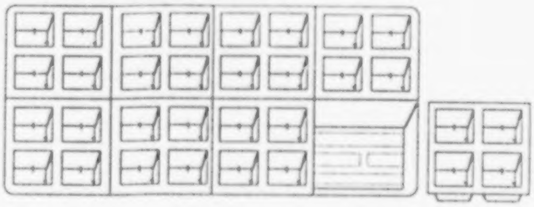
Bedding plant packs may be sold as sheets (flats) or may be cut apart and sold as individual units. In the bedding plant pack, each plant grows in its individual cell and its root ball pops out easily for transplanting into the garden. One sheet of bedding plant pack will fit one standard-sized plastic flat measuring approximately 10 by 20 inches. Perennial herbs, bedding plants, and garden vegetable plants are some examples of plant materials typically grown in bedding plant packs.

Plastic flats - Plastic flats come in several sizes but the standard size is approximately 10 inches by 20 inches. They can be used to hold bedding plant packs and individual containers, or for germinating seeds and starting cuttings. These multi-purpose

Figure 16.3 - Bedding Plant Packs

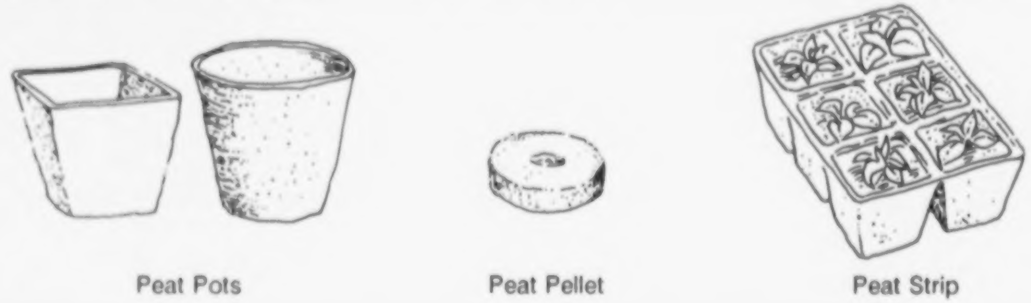


"812"



"804"

Figure 16.4 - Peat Containers



Peat Pots

Peat Pellet

Peat Strip

plastic flats may be solid or mesh, with or without drainage holes, with or without handles, and either lightweight or heavyweight grade plastic.

Peat containers - Many different kinds of plants are started in peat containers, especially bedding plants and garden vegetable plants. Figure 16.4 illustrates several of the different kinds of peat containers available. Peat pots are usually 2 to 3 inches wide and are made from peat moss that has been pressed into thin sheets and then molded into the typical pot shape. Peat moss can also be compressed into pellets. Once moistened, these pellets swell in size into a 1.5- by 1.5-inch self-contained growing unit, surrounded by a thin plastic net. Peat pots are designed to hold growing media; peat pellets are designed for direct seeding or insertion of plant cuttings and require no media.

A peat strip is a peat container that is made up of many square peat pots (usually 6 or 12) joined together at the top to make one single unit, which is then set into a plastic flat. Plants grown in peat strips may be sold as a group or cut apart and sold separately.

Peat containers are 100 percent natural and seedling roots may grow through them and eventually emerge from the sides. The well-rooted plant and the peat pot are both transplanted into the garden as one unit, insuring a minimum of root breakage and transplant shock. When kept constantly moist, peat containers will last for two months before they start to crumble. Peat containers must never be allowed to dry out; this will result in root damage. In addition, peat moss products are extremely difficult to thoroughly re-wet.

Summary

Containers for growing plants may be made from many materials, each having advantages and disadvantages. The most commonly used containers in the commercial greenhouse are composed of plastic, clay, or peat moss. Many types, sizes, and colors of containers are available for commercial production and for decorative use. The growth habit of the floriculture crop and the intended market are the primary factors for determining the optimal choice of container composition and shape.

Credits

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McDaniel, Gary L. Ornamental Horticulture. Reston, VA: Reston Publishing Co., Inc., 1979.

Tayama, H.K., et. al. Tips On Growing Ornamental and Vegetable Bedding Plants. Columbus, OH: Cooperative Extension Service.

Because water is such a critical component of the plant, proper watering is one of the most important operations carried on in greenhouse production. Although the task of watering appears to be simple, improper watering is the most frequent cause of crop damage and crop loss in the greenhouse.

Effects of Improper Watering

Underwatering - Wilting is the initial symptom of underwatering and occurs when the rate of water loss from the leaves of a plant (transpiration) exceeds the rate of water being taken up (absorbed) by its roots. Although wilting can occur even when there is adequate moisture available to the plant, it is most common when the growing medium of the plant has been allowed to dry.

When a plant wilts, its stomata (pores in the leaf surface responsible for gas exchange) close, thus preventing further water loss. Stomatal closure, however, prevents the entry of carbon dioxide into the leaf, thus reducing the plant's ability to carry on photosynthesis. Therefore, a water-stressed plant has a slower rate of growth than a non-stressed plant. Additionally a water-stressed plant has smaller leaves, shorter internodes, and harder, tougher tissue. When water stress is extreme, plant tissue dies. This shows itself as necrotic (dead or brown) leaf tips and margins.

Overwatering - Although overwatering would appear to have the opposite effect of underwatering, both have an initial similar effect on the plant and may ultimately lead to the plant's death. This is due to the fact that excess water in the root zone of a plant prevents oxygen, which is needed for the roots of a plant to stay healthy, from entering. Thus, overwatering injures a plant's roots, retarding its ability to absorb water. A plant that has been overwatered will appear much the same as an underwatered plant for the same reason: the rate of water loss exceeds the rate of water uptake. Additionally, excess water in the root zone encourages certain fungal diseases to attack and damage the plant's root system.

Rules of Proper Watering

Use a well-drained growing medium. - A plant should have sufficient water in its root zone to replace that lost by its shoot system while at the same time having adequate oxygen in its root zone to maintain the vigor of its root system. This condition can be maintained if a coarse, highly porous growing medium, such as a blend of peat, vermiculite, and perlite, is used. Such a medium will retain sufficient water (following drainage) to satisfy the needs of a plant for a reasonable length of time while at the same time be porous enough to supply adequate amounts of oxygen to the root system.

Water thoroughly at every watering. - Saturating the growing medium in a pot will make full use of the medium and its ability to store water for the plant, thus reducing the frequency of watering. Applying ten percent more water than the medium in a pot can hold will saturate the medium while at the same time leach out excess fertilizer salts that may build up in the growing medium. If salts are not leached, root damage (and death) may occur.

Water plants as needed. - More plants are damaged from overwatering than from underwatering, therefore care should be taken to water a plant only when it needs water. It is not always easy to tell if a plant needs water. A plant that is wilting is under moisture stress and should be watered only if the growing media appears dry. Certain plants do not wilt readily, even when under moisture stress. For these species, observing a change in color of the growing medium is helpful in determining when to water. Most media turn lighter in color as they dry. Touching the medium to feel its moisture status is also a useful method of gauging when to water, as long as your hands are clean and there are not pesticides on the growing medium.

Moisture Holding Capacity of a Growing Medium

The ability of a container of growing medium to retain water is usually determined by a struggle between the capillary forces of the growing medium (seeking to retain the water) and the force of gravity (seeking to "pull" water from the container). Two major factors influence this interaction: the porosity of the medium and the depth of the medium.

Porosity of the medium - The porosity of a medium refers to the ratio of water to air contained in the medium after being watered and allowed to drain. Growing media comprised of amendments of large particle size are porous and well-drained. This is because the large particles of medium form large (noncapillary) pores between each other. These pores are filled with air after being watered and allowed to drain.

On the other hand, growing media comprised of amendments of small particles are less porous and more poorly drained. This is because the small particles form small (capillary) pore spaces between them. These pores contain water after the medium is watered and allowed to drain. Gravity can remove the water from noncapillary pores by allowing air to enter but gravity cannot remove the water from capillary pores. Thus the extent to which a growing medium will contain both water and air after being watered and allowed to drain depends on the ratio of capillary to noncapillary pores. Again, a blend of peat, vermiculite, and perlite provides an ideal ratio of these two types of pores, thus retaining adequate water after drainage and leaving sufficient air for root growth.

Depth of the growing medium (height of the container) - As the depth of the growing medium increases with the height of the container, so does the length of the water column that exists from the top of the medium to the bottom. In taller containers, gravity is able to overcome the capillary force of the growing medium and pull water from the top portion of the container. In shallow containers, because of the relatively short water column, the capillary force of the growing medium is usually able to resist the pull of gravity, thereby retaining water within the container. Therefore, if the same medium is used in each container, there will be more water retained (by percentage of container volume) in a shallow container than in a tall container. See Figure 17.1. Additionally, in any container, there will be less water (and more air) per unit area near the surface of the medium than near the bottom. See Figure 17.2.

At times the height of the container is dictated by the requirements of a particular species (large plants need large containers) or by marketing strategy (some florists prefer smaller containers). Uniformity in water retention between different sized containers may be accomplished by adjusting the porosity of the growing medium. The use of a less porous medium in a tall container will provide for the added capillary force needed to retain water due to the height of the water column. Conversely, the use of a highly porous medium in a shallow container will provide for better drainage due to the decrease in capillary forces found in porous media, thus allowing gravity to remove more water. See Figure 17.3.

Figure 17.1 - Effect of depth of medium (container height) on relative amount of water retained

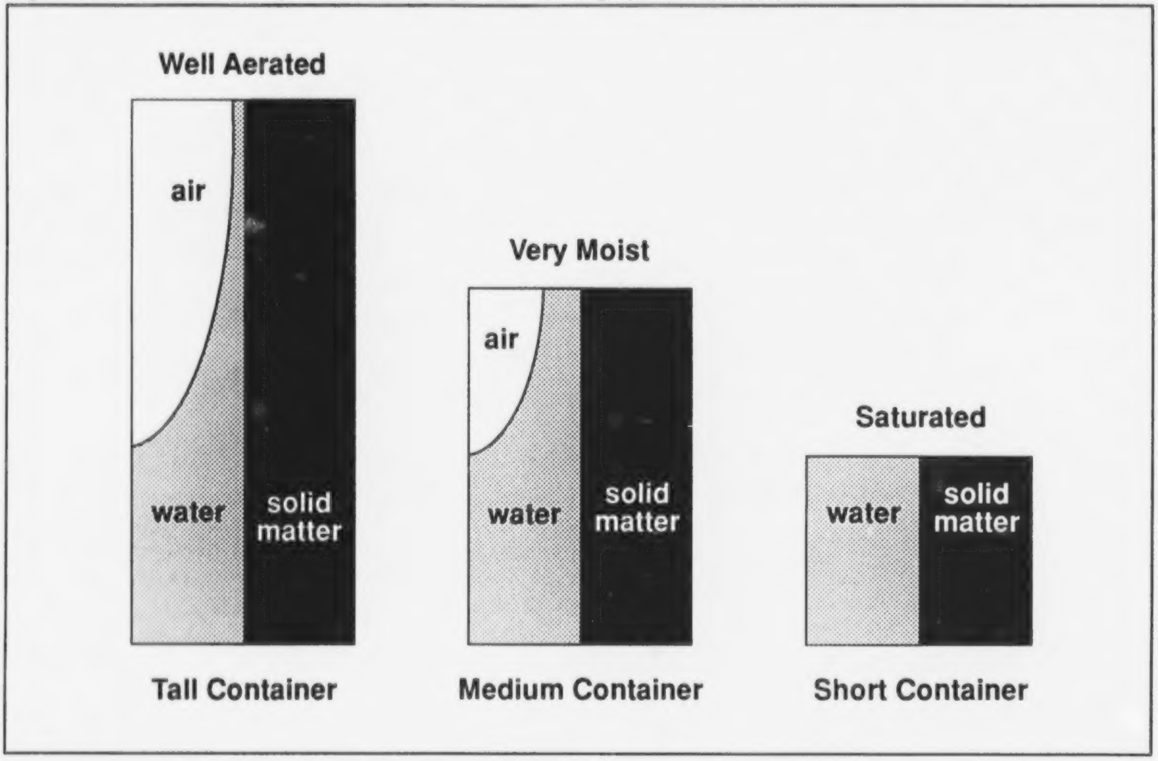


Figure 17.2 - Relative location of air and water in a container

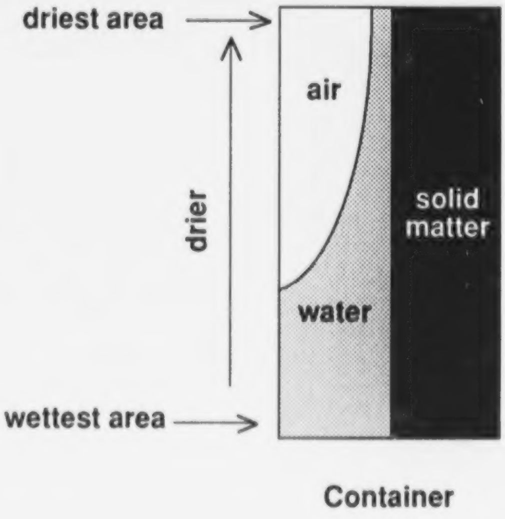
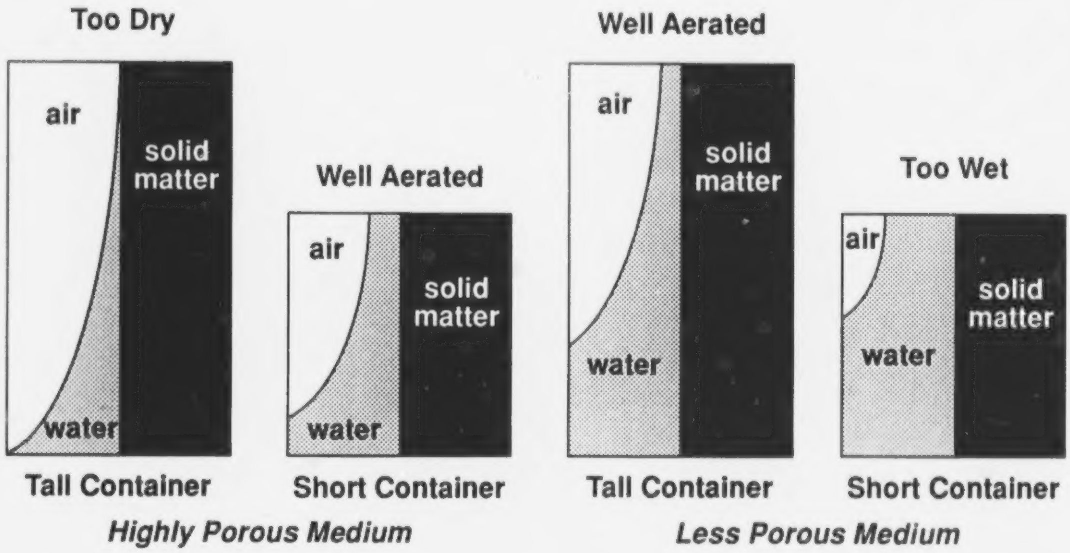

driest area
air
drier
solid matter
water
wettest area
Container

Figure 17.3 - Interaction between porosity of medium and container height on state of hydration of growing medium


Too Dry
air
solid matter
water
Tall Container
Well Aerated
air
solid matter
water
Short Container
Highly Porous Medium
Well Aerated
air
solid matter
water
Tall Container
Too Wet
air
solid matter
water
Short Container
Less Porous Medium

Overhead, Surface, and Subsurface Watering

Overhead, surface, and subsurface are the basic methods of watering greenhouse plants. The advantages and disadvantages of each method are discussed below. Refer to Lesson 5 for the equipment used for each application method.

Overhead - Overhead watering refers to any watering system that waters plants from above, thereby wetting its foliage in the process. Although commonly practiced in greenhouse operation, overhead watering has several drawbacks. Since moisture leads to many foliage diseases, plants watered from overhead are more prone to disease. Additionally, if nutrients are incorporated into the watering system, the salts in the nutrients will remain and stain the plant's leaves as the wet foliage dries. Also, overhead watering can cause puddles to form on the medium or can wash the growing medium from the container. It may even wash out an entire plant if newly transplanted. A water breaker should always be used when hand watering to reduce these risks.

Surface - Surface watering refers to any system that applies water below the foliage right at the surface of the growing medium. This is most desirable since the plant's foliage is not wetted, thus reducing the risk of disease and salt residue. Also, washing and puddling are much less of a problem with surface watering. The cost of most surface systems is greater than for overhead, although automated systems are available that can offset equipment costs with labor savings.

Subsurface - Subsurface watering refers to any system in which water is applied below the plant and allowed to enter the root zone via the capillary action of the growing medium. Wick watering a pot of African violets is a good example of subsurface watering.

There are several prerequisites for successful subsurface watering. First, there must be contact between the source of water and the growing medium. In the example just cited this contact is provided by a wick that extends from the medium to a reservoir of water below the pot. Second, the growing medium must have sufficient capillarity to allow the water to climb up the medium against the pull of gravity. Also, since the medium will be constantly moist in most subsurface systems, the growing medium must have some porosity to allow oxygen to enter the root system. If a nutrient solution is used as a water source, salt buildup in the medium is a potential problem. This can be overcome by periodically leaching the medium with clear water from above.

Summary

Water is a key component for plant growth. Understanding the results of improper watering, the factors that affect the growing media's ability to retain water, and the various systems by which water can be applied, one can manipulate water to achieve optimum growth.

Credits

Ball, Vic, ed; Geo. J. Ball, Inc. Ball Red Book - Greenhouse Growing. 14th ed. Reston, VA: Reston Publishing Company, Inc. (A Prentice-Hall Company). 1985.

Mastalerz, John W. The Greenhouse Environment. New York: John Wiley and Sons, 1977.

Nelson, Paul V. Greenhouse Operation and Management. Reston, VA: Reston Publishing Co., Inc., 1985.

Fertilization of Greenhouse Crops

Greenhouse-grown floriculture crops have the highest fertilizer, or plant food, requirements in all of agriculture. Generally grown in containers that restrict root development, such plants are encouraged to make maximum growth by the ideal environment in the greenhouse. One acre of chrysanthemums, for example, will require 4,000 pounds (1,800 kilograms) of nitrogen per year. The correct amount of fertilizer must be available at all times to achieve optimum growth and development of plants. Nutrient deficiencies that stunt or delay growth and nutrient excesses that are toxic to plants must be avoided.

By encouraging optimal plant growth, the greenhouse operators can produce a salable crop in the least possible amount of time; the quicker the crop turnover, the more profit for greenhouse owners.

Essential Elements for Plant Growth

The elements available in unlimited amounts from the atmosphere are carbon (C), hydrogen (H), and oxygen (O). All of the remaining required nutrients for plant growth are absorbed in mineral form by the plant's root system. The macronutrients, which are needed in large amounts by plants in order to grow well, are nitrogen (N), phosphorus (P), and potassium (K). Moderate amounts of the secondary macronutrients of calcium (Ca), magnesium (Mg), and sulfur (S) are required by plants. Only tiny amounts of the micronutrients, or trace elements, are necessary. There are seven micronutrients including: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). These elements or nutrients required for plant growth may be remembered by the following mnemonic device: "C HOPK'NS CAFE Mighty Good and CLean MaNaged By CUZN MO." Table 18.1, Essential Plant Nutrient Guidesheet, provides more information about these elements.

The Major Nutrient Deficiency Symptoms

Some common nutrient deficiency symptoms include slow plant growth, stunted growth, discoloration of the foliage (especially yellowing), excessively small new leaves, and leaves which drop off prematurely. Many other symptoms are

Table 18.1 - Essential Plant Nutrient Guidesheet

Nutrient	Nutrient name	Chemical symbol	Most available at a pH of	Main source(s)	Main use by the plant
Unlimited					
Nutrients available in unlimited amounts	(1) Carbon	C	N/A	CO_2	Carbohydrates
	(2) Oxygen	O	N/A	CO_2 and Water	Carbohydrates
	(3) Hydrogen	H	N/A	Water	Carbohydrates
Macronutrients					
Large amounts need to be added to soil to to grow good crops	(1) Nitrogen	N	6.0-8.0	Ammonium nitrate	Proteins
	(2) Phosphorus	P	6.5-7.5	Triple superphosphate	Energy carriers, DNA
	(3) Potassium	K	6.0-7.5	Muriate of potash	Enzyme activation
Secondary nutrients					
Medium amounts need to be added to soil	(1) Calcium	Ca	7.0-8.5	Dolomitic lime	Middle lamella
	(2) Magnesium	Mg	7.0-8.5	Dolomitic lime	Chlorophyll synthesis
	(3) Sulfur	S	6.0-10.0	Superphosphate or aluminum sulfate	Amino acids, vitamins
Micronutrients					
Tiny amounts need to be added to soil	(1) Iron	Fe	4.0-6.5	Iron-EDTA	Chlorophyll synthesis
	(2) Zinc	Zn	5.0-7.0	Zinc sulfate	Enzymes and enzyme activation
	(3) Manganese	Mn	5.0-6.5	Manganese sulfate	Photosynthesis
	(4) Molybdenum	Mo	7.0-10.0	Ammonium molybdate	Nitrogen metabolism
	(5) Boron	B	5.0-7.0	Borax	Membranes
	(6) Chlorine	Cl	N/A	Rainfall	Photosynthesis
	(7) Copper	Cu	5.0-7.0	Copper sulfate	Photosynthesis

Credit: Helsel, Diana G.; Judith A. Wells. "The Worksheet: An Under-Valued Learning Device," Journal of Agronomic Education. Madison, WI: American Society of Agronomy, Vol 14, No. 2, Fall 1985.

Table 18.2 - A Key to Nutrient Deficiency Symptoms

1. Effects general on whole plant or localized on older, lower leaves.
    2. Effects usually general on whole plant, although often manifested by yellowing or dying of older leaves.
        3. Foliage light green. Growth stunted, stalks slender and few new breaks. Leaves small, lower ones lighter yellow then upper. Yellowing followed by a drying to a light brown color. Leaves sometimes drop, or may remain attached. **(Nitrogen deficiency)**
        3. Foliage dark green. Delayed growth. Lower leaves sometimes yellow between veins but more often show a tendency to develop a purplish coloration, particularly on the petiole. Leaves dropping early. **(Phosphorus deficiency)**
    2. Effects usually local on older, lower leaves.
        3. Lower leaves mottled, usually with necrotic areas near tips and margins. Yellowing begins at margin and continued toward center. Margins later become brown and older leaves drop. **(Potassium deficiency)**
        3. Lower leaves chlorotic and usually show necrosis in late stages. Chlorosis appears between the veins, and veins remain normal green. Leaf margins may curl upward or downward and develop a puckered effect. **(Magnesium deficiency)**
1. Effects localized on new leaves.
    2. Terminal bud remaining alive.
        3. Leaves chlorotic between the veins; veins remain green.
            4. Only the larger veins remain green. Extreme cases show necrosis of margins and tip of leaf which sometimes extend inward, developing large areas. **(Iron deficiency)**

        NOTE: Certain cultural factors such as high pH, overwatering, cold soil temperatures, root rots, and nematodes may cause the same symptoms.

            4. Checkered or finely netted effect produced by even the smallest veins remaining green. **(Manganese deficiency)**
        3. Leaves light green, vein lighter than adjoining interveinal areas. **(Sulfur deficiency)**
        3. Leaves light green, but turning yellow at edges at first, and in severe cases becoming brown and necrotic. **(Molybdenum deficiency)**
    2. Terminal bud usually dies.
        3. Break down at tip and margin of young leaves. Young leaves often definitely hooked at tip. Death of roots actually precedes all of the above symptoms. **(Calcium deficiency)**
        3. Break down at base of young leaves. Stems and petioles brittle. Death of roots, particularly the meristematic tips. **(Boron deficiency)**

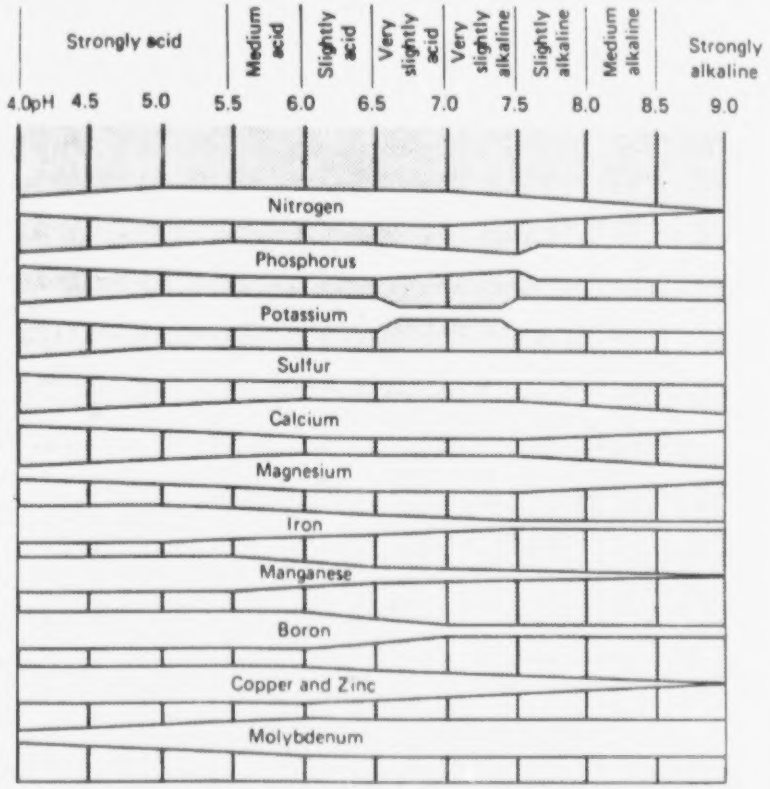
Adapted from: Laurie, Alex; D.C. Kiplinger. Commercial Flower Forcing. 5th ed. New York: McGraw-Hill Book Co., 1948.

possible as well. Nutrient deficiency symptoms will vary according to the type of plant and cultivated variety. Also, a plant may show several symptoms due to multiple nutrient deficiencies. Sometimes a plant will exhibit symptoms which may look like they are due to a nutrient deficiency, but are actually caused by something in the environment (e.g., caused by water stress or low temperature). Environmentally-caused symptoms are also known as physiological symptoms. Consequently, determining the precise cause of a plant symptom is often challenging and difficult.

To help pinpoint a nutrient deficiency, a key organized according to descriptions of plant symptoms may be used. Table 18.2, "Key To Nutrient Deficiency Symptoms" works by the process of elimination. To properly use the key, first examine the plant. Decide if the symptoms are best described by the first point 1 (effects general of whole plant or localized on older, lower leaves) or by the second number 1 (effects localized on new leaves). For example, if the symptoms are found only on the older, lower leaves, continue with the first point 1 and eliminate the second point 1.

The next step is to decide between the first point 2 (symptoms found mostly on the whole plant) and by the second point 2 (symptoms found on older, lower leaves). In this example, the symptoms are found localized on the older, lower leaves, hence eliminate the first point 2. If the symptoms are leaf drop of lower leaves and yellowing of leaves, starting at the edges and continuing toward the center, then it is described by the first point 3. Its description reads as follows: "Lower leaves mottled, usually with necrotic (dead

Figure 18.1 - Affect of Growing Medium pH on Nutrient Availability



Maximum availability is indicated by the widest part of the bar

Adapted from: Helsel, Diana G.; Judith A. Wells. "The Worksheet: An Under-Valued Learning Device," Journal of Agronomic Education. Madison, WI: American Society of Agronomy, Vol 14, No. 2, Fall 1985.

or brown) areas near tips and margins. Yellowing begins at margin and continues toward center. Margins later become brown and older leaves drop." This describes the plant symptoms of potassium (K) deficiency. Use this key to help identify each nutrient deficiency symptom evident on the plant.

Growing Medium Testing

General properties - The growing medium's properties in general may be checked regardless if the medium is soil-based or soilless. The University Extension offers testing of soil-based media for a fee. Private firms will test soilless media. The tests will show the amount of nutrients available in the growing medium. The results of the tests can be used to evaluate the current fertilization program and to make adjustments, if needed.

pH - The growing medium pH may be checked. The pH level measures the soil's acidity (presence of H^+ ions) or alkalinity (presence of OH^- ions). The most acidic reading is a pH of 1.0; 7.0 represents a neutral pH; and the most alkaline or basic reading is a pH of 14.0. It is important to remember that pH values are logarithmic (i.e., a pH of 8.0 is ten times more alkaline than a pH of 7.0 and a pH of 6.0 is ten times more acidic than a pH of 7.0). Hence, a slight pH change will dramatically affect the growing medium. Although plants vary in pH requirements, most greenhouse-grown crops flourish at a pH of 5.5-6.5. As fertilizer residues accumulate in the medium and as residues from the water supply build up, the pH changes.

As a commercial flower grower, it is especially important to keep track of the growing medium pH because most of the essential nutrients are available for uptake by the plant roots only within specific pH limits (Figure 18.1). For example, phosphorus is most available to plant root systems when the pH ranges between 6.5 and 7.5. If the growing medium pH reaches 8.0 or falls into the more acidic range, very little phosphorus is available to the plant.

Each nutrient element (except for carbon, oxygen, hydrogen, and chlorine) has its own optimum pH range where it is readily taken up by plant roots. At other pH levels than the optimum range, the nutrient is less available to the plant roots. Growing medium pH may easily be determined by a pH meter. Various types of pH meters are

Table 18.3 - Guidelines for Interpreting Soluble Salts Readings in mhos/cm
(Based on a 1 part medium to 2 parts water dilution)

Soil Mixes	Peat-lite Mixes*	Interpretation
0.1 - 0.2	0.1 - 0.5	Nutrient level very low; plants may be nutritionally starved; good as a starting point.
0.2 - 0.5	0.5 - 0.8	Low for medium high in organic matter
0.5 - 1.0	0.8 - 1.2	Medium; satisfactory for established plants; may be high for seedlings; good for salt sensitive plants (e.g., African violets)
1.0 - 1.2	1.2 - 1.8	High; satisfactory for established plants that are not allowed to run dry; too high for seedlings and cuttings; leaching may be necessary in a soil-based mix
1.2 - 2.0	1.8 - 3.0	Very high; plants may be stunted or wilted with apparently adequate growing medium moisture present; plants may appear to be nutritionally deficient; leach with water
Above 2.0	Above 3.0	Excessively high; no apparent growth as well as symptoms described above for established plants; seedlings and cuttings frequently killed

*Use this column for any peat- or bark-based media

Credit: Floriculture Extension Newsletter. University of Missouri-Columbia.

available from greenhouse supply firms. Carefully follow the procedures and directions according to the pH meter used.

Soluble salts - The amount of soluble mineral salts accumulating in the growing media may be examined. This buildup of soluble salts originates from irrigation water, fertilizer residues, and from the growing medium itself. Insufficient nutrient levels will slow down plant growth, but high levels of soluble salts may injure or kill plant roots. A quick and easy method of determining soluble salts is by using a salinity meter. In using this device, a sample of growing medium is mixed with water and stirred. Then the soluble salts reading is taken directly of this solution to determine mineral salt content. Refer to Table 18.3 for general guidelines for interpreting soluble salts readings.

Fertilizer Categories

The two main categories of fertilizers are those made from organic sources (i.e., from once-living sources) and those from inorganic sources (i.e., manmade from nonliving sources such as minerals). Organic sources of fertilizer (e.g., cottonseed meal, soybean meal, fish meal, dried blood, bone meal, animal manures, and sewage sludge) slowly release their nutrients as they decay. However, a lack of moisture and/or low temperatures greatly reduce the breakdown of organic material, thereby greatly slowing down the rate of nutrient release in the soil. Organic fertilizers contain relatively low nutrient percentages per unit bulk; thus, large amounts of the fertilizer source are required.

Inorganic fertilizers quickly release their nutrients to plants, are readily available for plant use, are widely distributed, and are only moderately expensive. One disadvantage of inorganic fertilizers is that they are highly concentrated and they easily burn leaf tissue; therefore, inorganic fertilizers must be measured carefully and used frequently in small amounts. Inorganic fertilizer is prepared in precise formulations including all 16 nutrients necessary for good plant growth. Figure 18.2 illustrates the kind of information found on a fertilizer label.

Forms of Fertilizers

Fertilizers are available in various forms. The most common is dry granules that are dissolved in water and then applied to the growing medium. Some dry fertilizers are designed to be mixed into the growing medium prior to planting. Other dry forms are applied as a top dressing to the soil

Figure 18.2 - Typical Fertilizer Label

USA reg. 000-0000

EASTER LILY FERTILIZER 16-4-12

Net Weight 50 Pounds

GUARANTEED ANALYSIS

TOTAL NITROGEN (N) 16%

9.97% NITRATE NITROGEN
1.05% AMMONIACAL NITROGEN
4.98% UREA NITROGEN

AVAILABLE PHOSPHORIC ACID (P_2O_5) 4%

SOLUBLE POTASH (K_2O) 12%

Primary Plant Nutrient Sources: Nitrate of Soda, Urea, Ammonium Phosphate, Potassium Nitrate

Potential Basicity 73 lbs. Calcium Carbonate Equivalent Per Ton

Manufactured by: Fertilizer Products Co., Anytown, USA surface. Dry fertilizers may also be formed into tablets or spikes, which are inserted in the soil. Dry fertilizers can be specially prepared to release their nutrients over a long time period; these are called slow-release or controlled-release fertilizers.

Slow-release fertilizers are only slightly water soluble. Their nutrients are released over a period of weeks or months. Some slow-release fertilizers have a plastic coating, which contains small pores, over small granules of nutrients. For best results, follow application directions on the label. There are several slow-release fertilizers that supply only trace elements or micronutrients.

Fertilizer Application

When planning a fertilizer program, directions for the the amount of fertilizer and frequency of application need to be carefully followed to prevent damage to the plant. If too much or too little fertilizer is applied, plant growth is adversely affected. Also, plant growth is affected if fertilizer is applied too frequently or infrequently. Too little fertilizer or infrequent applications will result in plant nutrient deficiencies. Too much fertilizer or excessive applications will cause the fertilizer to poison and injure the plant.

Before applying any fertilizer, make certain that the medium is moist. Never apply a fertilizer to dry medium, as this may result in root injury. When incorporating a dry fertilizer powder or granules into the growing medium, always water the medium before transplanting a plant into it.

Dry granular and liquid water soluble fertilizers are usually inorganic, highly refined, pure, easily dissolved in water, readily leached from the growing medium, and immediately available for uptake by plant roots. They are quick-acting, but they need to be reapplied often and can injure plants if applied at too high of concentrations. Water soluble fertilizers are often used in watering systems with a hose syphon, or with other types of fertilizer injectors or proportioners.

One common method of applying fertilizer is supplying a low concentration of fertilizer during every watering (i.e., constant liquid feeding or CLF). A "rule of thumb" for fertilizer concentration in the absence of another more specific guide would be to supply about 200 ppm N from a balanced, complete fertilizer with every watering. Most crops respond well to this level of CLF, as long as each watering is heavy enough so that a certain amount of leaching (i.e., applying sufficient water that it runs from the drainage holes in the bottom of the pot) occurs. This will prevent damaging accumulation of fertilizer salts in the growing medium.

The Fertilizer Formula

A fertilizer containing the elements nitrogen, phosphorus, and potassium is known as a "complete fertilizer." Of course, such a fertilizer is not really complete because the other 13 essential elements may be missing, but nitrogen, phosphorus, and potassium are the most important. The label on each bag of fertilizer states the analysis formula (e.g., 20-20-20) of that fertilizer. Refer back to Figure 18.2. Each number is the percent by weight of that element. The first number represents the amount of nitrogen (N) present. The second number stands for the amount of phosphorus expressed as phosphoric acid, or P_2O_5. The third number indicates the amount of potassium expressed as K_2O. Therefore, the label 16-4-12 means that the bag of fertilizer contains by weight 16 percent N, 4 percent P_2O_5, and 12 percent K_2O.

Fertilizer Concentrate for the Stock Tank

The fertilizer concentration of a stock solution is usually determined by the parts per million (ppm) of nitrogen in to be fed to plants, although it may be based on any nutrient.

Various fertilizer injectors or fertilizer proportioners have different preset dilution ratios, generally between 1:12 and 1:500. For example, an injector having a 1:128 ratio means that for every 129 gallons of water and fertilizer mixture applied to the plants, 128 gallons would be pure water and one gallon would be the stock fertilizer solution. When using fertilizer injectors with several settings, always double check the dial for the dilution being used.

Figure 18.3 - Fertilizer Formula for Stock Solution

$$\frac{\text{injector ratio:1}}{\text{\% nutrient in dry fertilizer}} \times \frac{\text{desired ppm nutrient}}{100} \times 1.35 \times \text{Gal. in stock tank} = \text{No. oz. of fertilizer for stock solution}$$

The number of ounces of dry fertilizer to be added to water to form a stock solution for use in an automatic fertilizer injector or fertilizer proportioner can be determined by using the formula in Figure 18.3.

For example, a floriculturist desires to feed 300 ppm nitrogen of a 15-16-17 dry fertilizer using a 1:128 injector ratio. The stock tank holds 5 gallons.

$$\frac{128}{15\%} \times \frac{300}{100} \times 1.35 \times 5 \text{ gal.} = \text{oz. fertilizer}$$

$$8.53 \times 3 \times 1.35 \times 5 = 172.75 \text{ oz. of dry fertilizer}$$

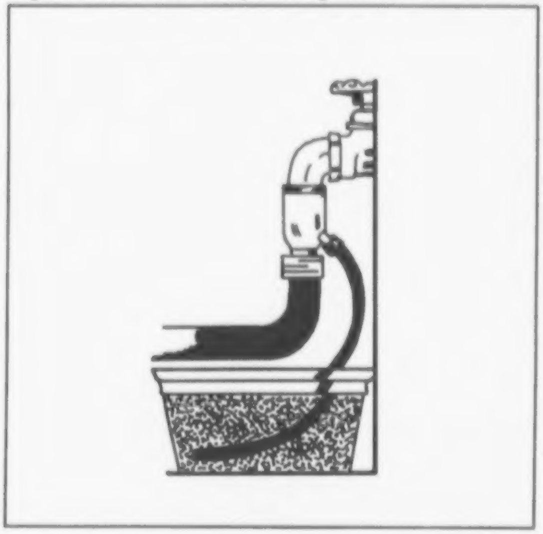
Calibrating a Siphoning Fertilizer Injector

A siphoning-type fertilizer proportioner is often used in small greenhouses for applying fertilizers to plants. Generally a hose siphoning proportioner hose is used with a hand-held watering hose, however, it may also be connected with a spaghetti tube watering system.

The hose siphoning device is connected between the water outlet and the hose, with a small diameter tube extending down from the siphon into a pail of concentrated fertilizer stock solution. As water flows into the hose and past the tiny opening in the hose siphon, a suction is created which pulls the fertilizer solution up into the tube and into the water stream flowing through the hose. See Figure 18.4.

Note that the dilution ratio (amount of fertilizer solution sucked up by the tube divided by the diluted fertilizer leaving the hose nozzle) will vary slightly due to fluctuations in water pressure. The amount of back pressure on the system created by different sized nozzles will also cause variation in the dilution ratio. However, this slight fluctuating dilution ratio will be safe for general purpose use in the greenhouse.

Figure 18.4 - Hose Siphoning Device



A hose siphon is a durable, inexpensive, easy to use, and fairly accurate way of measuring fertilizer amounts applied to plants. One disadvantage of this method is that the siphon causes reduced water flow through the hose, lengthening watering time. Also, because it is attached to a single hose, the hose siphon is incapable of watering large numbers of plants quickly.

In order to use the hose siphon device properly, the dilution ratio must first be calculated, since it will vary with water pressure. To calibrate the hose siphon, place a small quantity (1 quart) of concentrated fertilizer stock solution (containing a dye) in a pail. Insert the hose siphon into the pail and turn on the hose full force. Once the solution from the hose's end changes to the color of the dye, catch all the solution flowing from the hose. Stop collecting the solution when the solution from the hose turns back to clear water. Measure the amount (in quarts) of solution that flowed through the hose during the time it took to deplete the quart of fertilizer stock solution.

Finally, calculate the hose siphon dilution ratio. For example, 12 quarts of water went through the hose siphon as the quart of concentrate solution was drawn from the pail, resulting in 13 quarts being measured. The dilution ratio would be one quart concentrate solution to 12 quarts water or 1:12. Use the calculated dilution ratio to determine the amount of dry fertilizer that needs to be added to the concentrated fertilizer stock tank when using a hose siphon.

Summary

Greenhouse-grown crops must receive proper nutrients in order to achieve optimum growth. The faster the growth rate, the quicker the plants may be sold, hence increasing the economic return for the crop. To achieve this goal, it is important to apply the proper amounts of the 16 essential nutrients required for optimum plant growth. Thus, nutrient deficiencies and their resulting adverse plant symptoms, can be avoided. Nutrient and pH levels may be determined by testing the soil. The formula on the fertilizer bag states the percentage, by weight, of the nutrient elements nitrogen, phosphorus, and potassium. Fertilizers are available in various forms such as dry granules or liquids. It is necessary to calculate the ppm of different fertilizers especially when preparing the fertilizer concentrate for a stock tank solution. To apply the correct amount of fertilizer, it is important to understand how to calibrate a hose siphon fertilizer injector.

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A greenhouse is actually a "tropical oasis" for certain insects. The plants growing there never lack warmth or moisture, and are in a constant state of lush growth. Pests living with these plants are never exposed to below-freezing temperatures, or conditions of extreme drought, as long as normal plant growing conditions are maintained. Severe pest infestations of outdoor plants in temperate climate zones are frequently halted by unfavorable weather conditions such as winter freezes, which stop their rapid and continuous multiplication and cause them to enter "dormant" stages before re-emerging the following spring. Because the greenhouse environment is maintained constantly favorable for rapid plant growth, such natural interruptions in the life cycle of pests rarely occur. Therefore, pests pose continuous problems to the greenhouse manager.

Common Greenhouse Plant Pests

Plant pests include all of the various living organisms that damage plants. A list of common greenhouse pests follows:

1. Arachnids are invertebrate animals characterized by eight legs, such as mites, spiders, and ticks.
2. Bacteria are one-celled organisms. Most bacteria lack chlorophyll and are parasites of either plant or animal cells.
3. Fungi are primitive parasitic plants characterized by being one-celled to multi-celled organisms without chlorophyll such as molds, mildews, and mushrooms.
4. Insects are invertebrate animals with six legs, a segmented body with three major divisions as an adult, and often two pairs of wings.
5. Mollusks are invertebrate animals characterized by soft bodies, such as slugs and snails.
6. Nematodes are invertebrate animals characterized by round, thread-like bodies, such as soil and foliar nematode roundworms.
7. Rodents are vertebrate animals, such as mice and rats.
8. Viruses are extremely small (smaller than a cell) organisms consisting of a strand of RNA (ribonucleic acid) core surrounded by a protein sheath; viruses are parasitic and live within individual cells.
9. Weeds are plants growing out of place; such unwanted plants are often found growing under greenhouse benches.

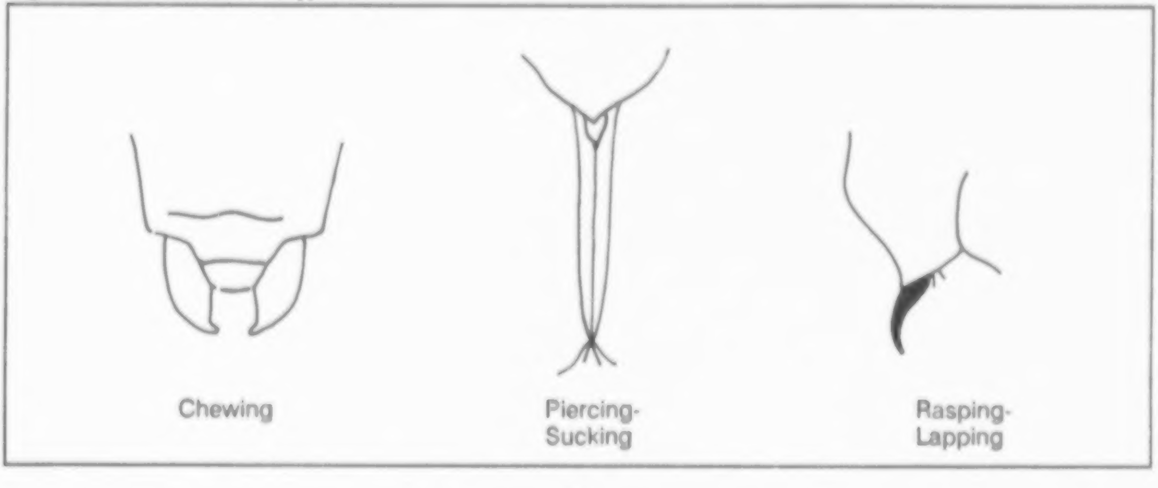
Of these pests, insects and mites represent the biggest problem for greenhouse plant production.

Insects gain entrance to greenhouses in many ways. They may simply fly in or be carried in on moving air currents from the outside when vents and doors are open. Lights inside the greenhouse at night attract moths and other flying adult insects. Later these adults lay eggs on the crops. These eggs hatch insect larvae that devour the leaves of the greenhouse crops. Florists who buy started plants or rooted cuttings from outside suppliers may sometimes unknowingly receive an insect "bonus" with their shipment.

Mouth and Body Parts of Insects

Before describing the major insect pests, it is

Figure 19.1 - Mouth Part Types



important to look at how they feed and thus damage greenhouse plants. Determined by how a species of insect feeds, there are various types of mouth parts. Only three types, those adapted for chewing, those adapted for piercing-sucking, and those adapted for rasping-lapping, are of interest to greenhouse managers. See Figure 19.1.

Some examples of insects that chew their food are the larvae of fungus gnats and shore flies, as well as grasshoppers. In such insects as thripss, the mouth parts are used to scratch the plant's epidermis and to lap up plant sap. This type of feeding apparatus is termed rasping-lapping. Insects with piercing-sucking mouth parts take in fluids, such as plant sap, in various ways. The mouth parts of aphids and scale insects have tiny sharp needles that pierce the epidermis of plants and then enter a cell or tap into the phloem to suck the plant sap.

All adult insects have bodies which are divided into three main parts - head, thorax, and abdomen. See Figure 19.2. In addition, all adult insects have three pairs of legs and a tough shell-like exoskeleton (outer covering to their bodies). Most insects also have a pair of antennae and two pairs of wings as adults.

Eight Major Greenhouse Pests

Aphids - Aphids, also known as plant lice, attack nearly every greenhouse-grown crop. In fact, the most common greenhouse insect pest is the green peach aphid. Aphids are visible to the naked eye, about 1/25-1/8 inch (1-3 mm) long, with soft bodies. Although aphids are usually some shade of green, they may also be red, yellow, brown, or black. See Figure 19.3. Frequently adult aphids will fly into the greenhouse. Aphids may often be found clustered underneath leaves or on young buds or stems.

Figure 19.2 - Major Body Parts

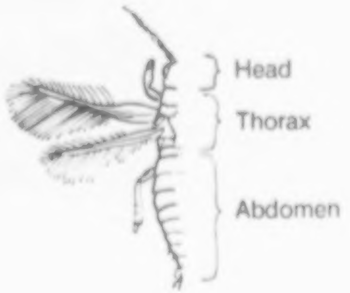
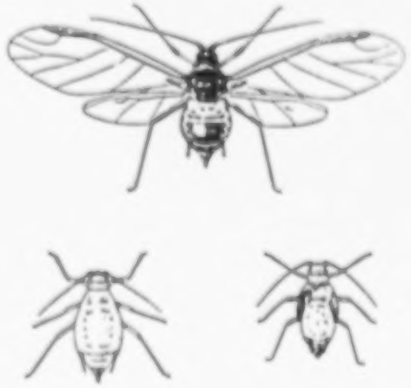


Figure 19.3 - Aphid



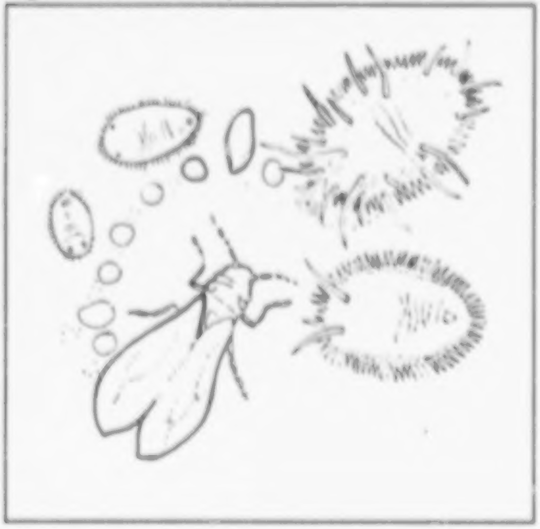
Using their piercing-sucking mouth parts, aphids suck the sugary plant sap from the phloem cells, causing stunting and distortion of new shoots. Perhaps even worse, aphids spread many bacterial and viral diseases from plant to plant. This insect generally attacks young floriculture crop plants. However, depending on the plant species, aphids may feed any time during the plant's life cycle. Thus, aphids are a year-round threat in the greenhouse.

Aphids give off honeydew, a sugary substance that serves as a food source for sooty black mold fungus. This fungus, growing on the upper plant parts, decreases the aesthetic value of the crop and also attracts ants. In addition, green foliage may become mottled with many pinpoint yellow spots (each tiny spot represents an aphid feeding site), further decreasing the plant's beauty.

Adult female aphids reproduce rapidly (i.e., each female produces about 100 offspring during her three-week life span). Repeated and frequent applications of insecticide are required to kill a population of aphids.

Whiteflies - These small, four-winged insects suck plant juices with their piercing-sucking mouth parts. Actually, whiteflies are misnamed, for they are not flies. Instead, they are close relatives of aphids, mealybugs, and scale insects. Whiteflies look like tiny white moths and are about 1/16 inch (2 mm) long. See Figure 19.4. Whiteflies like to congregate on the underside of foliage. When plant leaves are brushed, these insects are disturbed and fly around.

Figure 19.4 - Whitefly



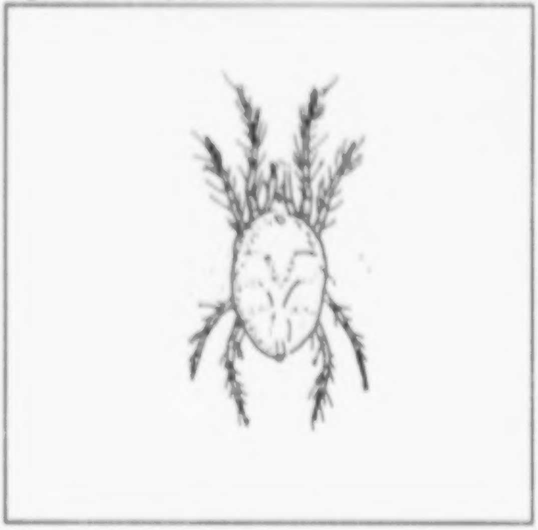
Whiteflies feed on many types of greenhouse crops, especially chrysanthemums, poinsettias, and bedding plants (e.g., fuchsias, lantanas, petunias, tomatoes, and other vegetable starter plants). Whiteflies are found year-round in the greenhouse. This insect's life cycle is about five weeks long.

Whiteflies can injure crop plants in three ways. First, whitefly feeding sites appear as tiny yellow spots on the foliage, decreasing beauty. Second, these insects, like aphids, give off honeydew, which promotes the growth of sooty black mold fungus on the leaves, also making the plant unattractive. Third, whiteflies can spread various plant diseases from plant to plant during feeding.

Adult whiteflies are most susceptible to being killed by pesticides. Repeated and frequent applications of pesticide are required. Whiteflies may be controlled by using trap crops such as fuchsias or lantanas. Because whiteflies are attracted to the color yellow, yellow boards, cardboard, or strips coated with a sticky substance are also used to physically trap these tiny flying insects.

Mites - Mites (e.g., cyclamen mites and red spider mites are greenhouse pests that are not insects; they are arachnids. Mites are relatives of scorpions, spiders, and ticks because they have eight legs as adults, while adult insects have only six legs. Although, mites are not true insects, they are listed here since they have similar feeding habits as insects and pose many of the same problems for greenhouse production.

Figure 19.5 - Spider Mite



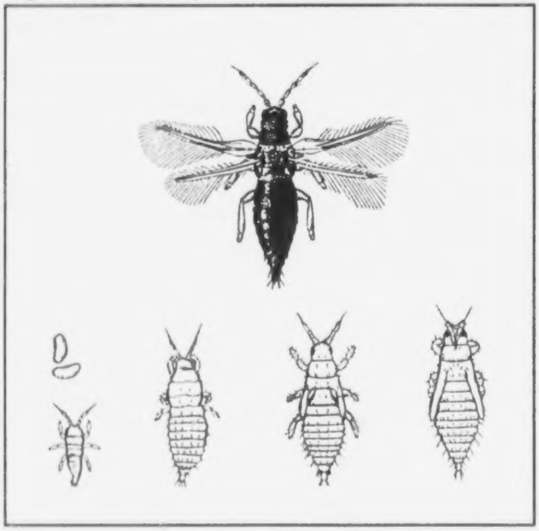
Common greenhouse mites may be red, green, or colorless. Mites are very small, less than 1/50 inch (0.50 mm) long. See Figure 19.5. They have piercing-sucking mouth parts and enjoy feeding on nearly all plant species. Wherever a mite feeds, the plant cells die and a tiny yellow dot appears. Curled leaves and bronze foliage may result as well. Finally, spider mites weave tiny webs throughout the foliage of the plant, which cause the leaves to turn brown. Mite damage results in a significant decrease of aesthetic beauty and therefore makes the plant unsalable. These arachnids can enter the greenhouse on infested plant material.

Mites reproduce rapidly; one adult female mite can lay about 100 eggs in her two- to four-week life span. Mites persist in the greenhouse because they adapt to the greenhouse's varying temperature and humidity levels. Some species of mites flourish in temperatures of about 60°F (16°C) and high humidity, while other mite species cause more serious damage while in high temperatures and low humidity.

Repeated and frequent applications of a miticide is necessary to control mites. This is especially true for red spider mites. In fact, red spider mites may be the most difficult greenhouse pest to control, as well as cause the most economic damage.

Thrips (used as both singular and plural forms) - Thrips are insects that are barely visible to the naked eye, approximately 1/25 inch (1 mm) long. See Figure 19.6.

Figure 19.6 - Thrips



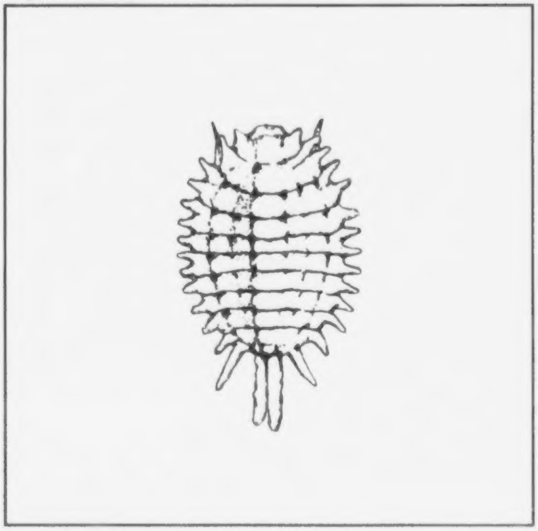
Thrips feed on many types of flower and vegetable plants, usually the tender buds, flowers, or axils of young leaves. These tiny insects use rasping-lapping mouth parts to scrape the surface of leaves or flower petals and lap up the released plant sap. Malformed new growth or misshaped flowers, along with the streaking and browning of flower petals, are symptoms of thrips damage. Thrips damage can also cause the leaves and flowers to fall off. In addition, thrips can carry viral diseases as they feed from plant to plant.

To check for the presence of thrips, tap a flower or bud over a sheet of white paper. The tiny black, brown, or yellow insects may be detected (moving) against the white background. Thrips can cause damage to greenhouse crops throughout the entire year. Frequent and repeated applications of insecticides are required to kill adult thrips, which have a two-week life span.

Since thrips may be carried into the greenhouse on wind currents, very fine screening should be used on all greenhouse vents and openings. Finally, vents should be located perpendicular to the prevailing winds as much as possible. Both of these precautions will decrease the number of thrips entering the greenhouse.

Mealybugs - Mealybugs are approximately 1/8 to 3/8 inch (3-4 mm) long, slow-moving insects, which are covered with a white, waxy powder. See Figure 19.7. Mealybugs like to congregate in leaf axils and underneath leaves where they lay their eggs. Egg clusters look like a tiny ball of cotton. Using their piercing-sucking mouth parts, mealybugs suck plant sap of many greenhouse plants. Symptoms are a loss of plant vigor, yellow deformed foliage, and a loss of leaves. Like aphids and whiteflies, mealybugs give off honeydew.

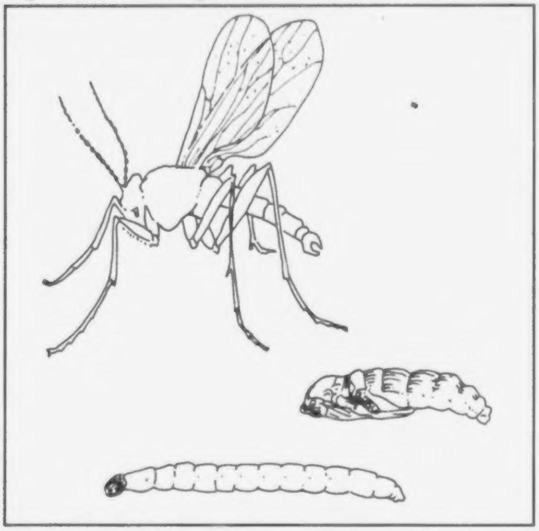
Figure 19.7 - Mealybug



These insects reproduce rapidly; one female mealybug can produce several hundred eggs during her 7- to 10-week life span. Adult mealybugs can crawl. Since both adult mealybugs and their egg masses are covered with wax, they are well-protected from pesticide sprays. This insect is easier to kill while in immature stages, and even then repeated and frequent insecticide applications are needed.

Fungus gnats and Shore flies - Fungus gnats are about 1/8 inch (3 mm) long with one pair of transparent wings. When disturbed, a cloud of these small black or gray insects will rise from the soil surface or from underneath plant foliage and fly to nearby plants. The adult fungus gnats do not feed on greenhouse plants. Crop damage is caused by the 1/4 inch (6 mm) long white worm-like larvae of these insects. See Figure 19.8. The larvae may attack tender roots or root hairs, resulting in the death of many varieties of young plants. With their chewing mouth parts, the larvae may also feed on the crowns of plants or on bulbs. They can enter the greenhouse on organic matter. Symptoms of plant damage due to these larvae include lack of plant vigor, stunted growth, wilted leaves, leaf drop, and yellow foliage.

Figure 19.8 - Fungus Gnat

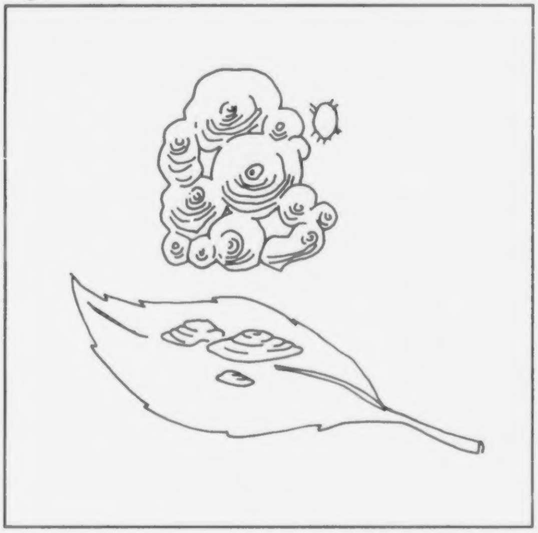


The life span of the fungus gnat is about four weeks. An adult female will produce up to 300 eggs, which are laid in the soil. This insect is a year-round pest in the greenhouse, especially when the crop plants are kept wet. Insecticides may be aimed at the larvae, which live in the growing media or the adult. Since some species of fungus gnats feed on fungi, it is important to discourage fungus growth as much as possible.

Shore flies are slightly larger relatives of fungus gnats. They have a similar life cycle to fungus gnats. Shore flies lay their eggs in peat moss, which is frequently purchased for growing medium. Once the eggs hatch, they attack many kinds of plants. Frequent and repeated insecticide applications are needed to control shore flies, as well as fungus gnat larvae.

Scale - Scale insects may grow up to 5/16 inch 8 mm) long and are close relatives to mealybugs. Some scale insects have a hard shell that protects them from pesticide sprays. Such shells or scales may be round or semi-round and colored white, gray, black, or brown. Other types of scale insects have a waxy or rubbery outer coating instead of hard protective shells. Only the latter type of scale insects give off honeydew, the food source for black sooty mold fungus.

Figure 19.9 - Scale

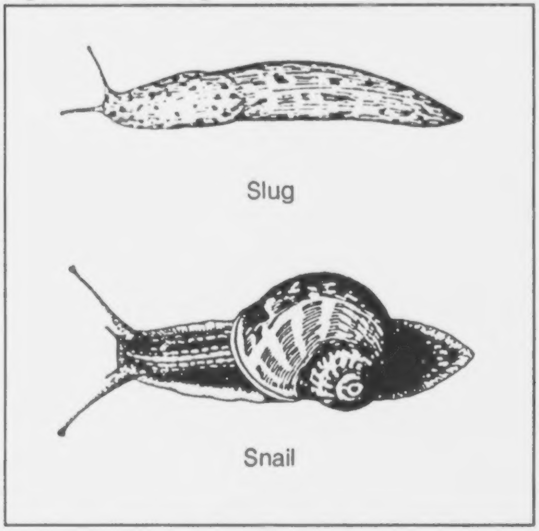


These insects insert their piercing-sucking mouth parts into plant cells and suck the plant sap of a wide variety of plants. As a general rule, scale insects are stationary while feeding, and look like roundish bumps on plant stems or leaves. Some symptoms of scale infestation include lack of plant vigor, stunted growth, yellow leaves, and leaf drop.

Some scale insect species reproduce by bearing live offspring, while other species lay eggs. The life span of scale insects varies from about two months to four months, according to the environmental conditions and the scale species involved. The most common means of entry into the greenhouse is on plant material. Frequent and repeated insecticide applications are required to control scale.

Slugs and Snails - Slugs and Snails are closely related mollusks that feed on plant foliage with their chewing mouth parts. In fact, these mollusks can completely strip the leaves from almost any type of greenhouse-grown plant. Slugs usually feed at night; during the day they hide in dark, moist places. Slugs can grow up to 4 inches (10 cm) long and have no shell. Snails are similar in anatomy to slugs, except that they possess a hard shell. Both of these pests may be detected by the shiny track or trail of slimy liquid left behind as they move over plant surfaces. These mollusks are usually gray, black, or brown. See Figure 19.10.

Figure 19.10 - Slug and Snail



Slugs and snails may enter the greenhouse from nearby fields or in soil-based media, flats, plants, etc., that are brought into the greenhouse. In the moist, warm greenhouse environment, slugs and snails are year-round pests. Clusters of up to 100 eggs are laid in damp places. Slug and snail may live up to one year. Place molluscicide baits, which attract slugs and snails, throughout the greenhouse to poison them. An alternate method would be to place shallow pans of beer around the greenhouse; the beer will attract these mollusks, which can then be collected and destroyed.

Three Categories of Plant Diseases

The three categories of plant diseases, grouped according to their causes, are as follows:

1. Diseases caused by living organisms (e.g., bacteria, fungi, and nematode worms)
2. Diseases caused by viruses - Being much smaller than a cell, a virus spends most of its life as a parasite living within a cell.
3. Diseases caused by nonliving or physiological factors (e.g., air pollution, adverse environmental conditions, poor nutrient levels)

Bacteria are one-celled organisms that nearly always lack chlorophyll. Sometimes they are regarded as an extremely primitive type of plant. Most bacteria are parasites, which obtain their nutrients from other cells. In floriculture, some common diseases caused by bacteria are black spot of rose, leaf spot of geranium, carnation wilt, and soft rot of iris.

Fungi are also considered to be a type of primitive plant. They are made up of one to many cells and lack chlorophyll. Like most bacteria, parasitic fungi must obtain their nutrients from either animal or plant cells.

Fungi reproduce by microscopic spores, which function similarly to seeds in higher plants. Spores of fungi are moved by air currents, by splashed water, and by man. They settle on a host plant where they proceed to grow new fungi bodies, thereby starting new infections. Some common fungal diseases include powdery mildew of roses, damping-off disease of germinating seeds/seedlings, botrytis or gray mold of geranium, and poinsettia root rot.

Although some species are visible to the naked eye, generally they are microscopic. Most nematodes are roundworms living in the top surface of the greenhouse soil. Some species, called foliar nematodes (e.g., foliar nematodes of chrysanthemum) invade plant leaves. Bulb nematodes attack bulbs of various plants (e.g., hyacinth) and root nematodes (e.g., tomato) attack roots.

Viruses cause various noncurable diseases on floriculture crops. Unfortunately, the only practical way to control a viral disease is to throw out the infected plant. Two examples of plant diseases caused by viruses are Aster yellow virus and Cattleya orchid mosaic virus.

Four Major Diseases of Greenhouse Crops

Damping-off - Damping-off disease is caused by one or several different types of fungi. If damping-off disease fungi are present on the seed or in the soil, then the seed may be destroyed before it germinates or before the shoot(s) emerge from the soil. This is termed "pre-emergence infection" and is usually caused by the fungi Pythium or Phytophthora. If the fungi attack the sprouted seedling at soil level, then the young plant usually falls over and dies. This condition is known as "postemergence" infection and is caused by a fungi called Rhizoctonia.

When damping-off disease is detected, the medium should be treated with a fungicide. If the disease spread is great, the plants must be discarded and the medium sterilized. Using a fungus-free seed sowing medium such as fine sphagnum moss is highly recommended. Be sure that the seed is clean and, even better, that it has been treated with a fungicide. Practicing strict sanitation measures, like washing the seed-sowing containers in a ten percent bleach solution and then rinsing them thoroughly in plain water prior to planting, is also helpful in preventing damping-off disease.

Botrytis or gray mold - Botrytis or gray mold fungus is probably the most costly disease of greenhouse crops to treat. A wide variety of plants may be affected. The symptoms of this fungal disease are gray spots (fuzzy masses of fungi spores), which may cover all the aboveground plant parts. Tissues beneath the gray spots turn soft and then become brown and rotten. Consequently, the plant becomes unsalable. Botrytis spores are spread from plant to plant by air currents. These spores must have water in order to grow. Dead, injured, weakened, and tender plant parts are most vulnerable to botrytis attack. To control this fungus, avoid splashing water on plants and lower the humidity level in the greenhouse.

Practice good ventilation and heating procedures to avoid water condensation on plant foliage. Remove all dead leaves, blooms, and other plant tissue debris promptly. Do not let water from hanging baskets drip onto plants underneath them. In general, good sanitation measures and maintaining a clean greenhouse are very helpful in preventing a botrytis attack. Various fungicides may be applied to crop plants to combat botrytis; always follow the instructions on the pesticide container label exactly.

Foliar diseases or leaf spot - Foliar diseases or leaf spot may be caused by either bacteria (e.g., bacterial blight leaf spot of geranium) or by fungi (e.g., powdery mildew of rose). Discolored leaves (white powdery spots of mildew) as well as distorted leaves are symptoms of leaf spot disease.

Since so few bactericides are available, it is recommended to avoid further contamination to promptly discard plants infested with bacterial leaf spot disease. Fungicide sprays may be used to control fungal leaf spot infection. Also, controlling the greenhouse heating and ventilation systems to achieve lower humidity will slow down the growth of fungal leaf spot diseases.

Root rot diseases - Root rot diseases, due to the fungus Pythium or Phythophthora and/or bacterial invasion, usually occur because of overwatering. In fact, root rot is the most common cause of houseplant death. When checking for root rot disease, turn the plant upside down and gently tap it out of its growing container. Next, carefully examine the roots. A healthy root system will show many white or light-colored roots and have an earthy odor. In contrast, a diseased root system will have only a few brown or black roots that look slimy and have a foul odor.

Since the plant's roots are damaged by root rot organisms, the uptake of water and dissolved nutrients by the root hairs will decrease. The resulting insufficient water and nutrient uptake may cause the following foliage symptoms: yellow leaves, wilted leaves, and leaf drop. The best method for preventing root rot is to use a pathogen-free, well-aerated, and well-drained growing medium. Never overwater plants. Practice good sanitation by cleaning all tools, potting benches, containers, etc., with a disinfectant such as a ten percent bleach solution. Make sure that all plant materials and rooted cuttings are disease-free.

Preventative measures also include drenching the growing medium with a fungicide. Be sure to follow pesticide label directions exactly. Unfortunately, bacterial plant diseases, including some types of root rot, are hard to control since few bactericides are available for greenhouse application. Consequently, plants infected with bacterial disease should be thrown away promptly.

Frequently, it is difficult to identify the disease-causing organism attacking floriculture crops. One recommended way to correctly diagnose a plant disease(s) is to consult with the local University Extension Center. Experts there will be able to help with disease identification or will direct you to the Extension Plant Pathology Laboratory at the University of Missouri-Columbia. Follow the directions given by the Extension agent exactly when submitting diseased plant samples to the Plant Pathology Laboratory.

Summary

The factors causing plant disease are (1) living organisms such as bacteria and insects; (2) viruses; and (3) nonliving or physiological factors such as poor nutrient levels and overwatering. It is important to understand pest anatomy when discussing the eight most common pests found in

Missouri greenhouses: aphids, whiteflies, mites, thrips, mealybugs, fungus gnats/shore flies, scale insects, and slugs/snails. Damping-off disease, botrytis (gray mold), foliar disease, and root rot disease are the four most common types of greenhouse diseases. It is important to properly identify greenhouse pests in order to control them effectively.

Credits

Laurie, Alex. The Greenhouse Worker. Columbus: Ohio Agricultural Education Curriculum Materials Service, Ohio State University, 1981.

Manaker, George H. Interior Plantscapes-Installation, Maintenance, and Management. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1981.

Nelson, Paul V. Greenhouse Operation and Management. 3rd ed. Reston, VA: Reston Publishing Co., Inc., 1978.

Pesticide and Target Pest

A multitude of pests cause problems in the commercial greenhouse, as well as in all of horticulture. Therefore, it is important to know what type of pesticide to use on each individual pest. See Table 20.1 for a pesticide - target pest listing.

Table 20.1 - Pesticide - Target Pest

Type of Pesticide	Target Pest
acaricide	mites, ticks
bactericide	bacteria
fungicide	fungi
herbicide	weeds
insecticide	insects
miticide	mites
molluscicide	slugs, snails
nematicide	nematodes
rodenticide	mice, rats

Methods to Control Plant Pests

Three goals should be kept in mind when planning for successful pest control. These goals are to protect the environment, select the best combination of pest control methods, and apply chemical pesticides only when necessary. Pests can be controlled by chemical pesticides, cultural practices, mechanical methods, good sanitation practices, and biological control measures.

Chemical pesticides - Chemical pesticides are usually the quickest and most effective method to eliminate pests. In fact, applying pesticide is the only sure way to kill many pests. Besides direct killing action, various pesticides are designed either to repel pests or to attract them for the purpose of killing them. In order to achieve the maximum lethal effect, it is extremely important to apply appropriate chemical pesticides at the proper time in the pest's life cycle. It is crucial to always follow pesticide label directions exactly. Remember to use chemical pesticides only when necessary.

Cultural practices - Cultural practices are methods implemented during the plant's growing phase to reduce pests. Cultural practices may alter the environment, change the condition of the host, or alter the behavior of the pest. For example, fuchsia plants may be used as a trap crop to attract whiteflies. These plants are treated with a systemic pesticide, which kills the pests when they feed on the plant.

Trap crops can also serve to attract pests as a preferred food source and, once collected, the trap plants and the feeding insects may be disposed of together. Varying the planting time as well as controlling greenhouse temperature and humidity levels represent other cultural practices used to control pests.

Mechanical methods - Putting screens around windows and fans can also decrease pest populations in the greenhouse. Many greenhouse managers hang insect traps made from lightweight boards, cardboard, or polyethylene strips that are colored yellow and coated with a sticky substance. Insects (particularly whiteflies and fungus gnats) are attracted to the bright yellow color; and when they land they are physically stuck to the surface. Thrips are attracted to the color blue, thus blue sticky cards are available to monitor them. Insect traps (e.g., ant and roach traps) are also used to trap and kill insects.

Sanitation procedures - Good sanitation is important to the prevention of pests in the greenhouse. To deter pests from entering the greenhouse, keep weeds removed from around the exterior of the greenhouse as well as under greenhouse benches. This denies pests food and shelter. Another type of sanitation strategy involves planting pest-free seeds and plant materials (e.g., cuttings and starter plants). Federal and state governmental agencies set sanitation standards governing the inspection of horticultural products, prior to sale and shipment to the commercial greenhouse.

Smoking or chewing tobacco products should be prohibited in the greenhouse, because tobacco products often carry the tobacco mosaic virus. This virus can severely damage certain floricultural crops. If workers use tobacco products outside the greenhouse, it is vital that they thoroughly wash their hands before touching plants.

Since the greenhouse floor frequently contains disease organisms, it is important to always keep the end of the water hose off the floor. If the hose end is contaminated, the disease organisms would be spread to the entire crop when watering. The greenhouse worker could unintentionally spread disease organisms and insects from the greenhouse floor by placing his or her feet on a bench, thus infesting the crop-growing area.

Biological control - Biological control can be achieved by introducing a natural enemy to control the plant pest. The pest's enemy must be introduced to crops at regular intervals to be effective. It is important to note that biological control measures are generally slow-acting and are seldom completely effective in controlling pests. Also, natural enemies are expensive to purchase. Consequently, biological controls are rarely used in the commercial greenhouse today, but they may become more popular as chemical pesticides are taken off the market. One example of a biological control measure would be to release tiny wasps that parasitize whitefly eggs and larvae, thus killing them.

Spraying an antibiotic preparation onto floriculture crops, such as chrysanthemums with bacterial wilt, would be another example of a biological control method.

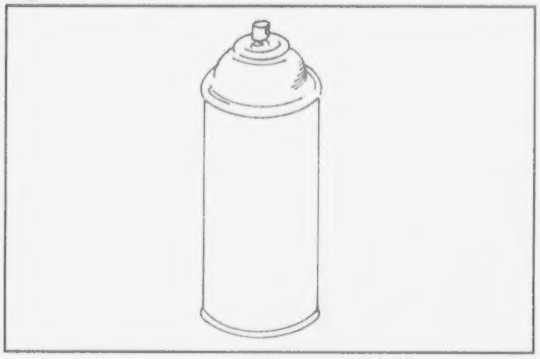
Plant crops with natural genetic resistance - Certain floriculture crops are naturally resistant to attacks by certain pests. Some varieties of plants may even be immune to certain pests. For example, African violet plants are not bothered by whiteflies. Furthermore, members of the Cactus Family are rarely attacked by pests.

Equipment Used to Apply Pesticides

Pesticide applicators are necessary for applying nearly all types of pesticides. The four main types of pesticide applicators commonly found in the commercial greenhouse are hand-held sprayers, power backpack sprayers, power wheelbarrow sprayers, and aerosol or fog generators.

Hand-held sprayers - Hand-held sprayers are useful in applying limited quantities of pesticides. They are easy to operate, inexpensive, and easy to maintain. But, in the case of the trigger pump, the contents of the sprayer, especially if it is a wettable powder, must be shaken often to keep the pesticide in suspension. Since sprayer output and pressure fluctuate, it is nearly impossible to apply exact quantities of pesticide. There are several types of hand-held sprayers.

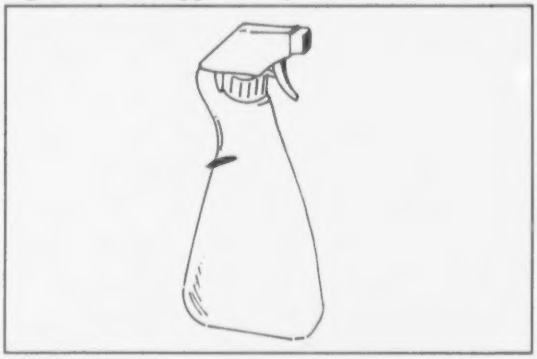
Figure 20.1 - Pressurized Can



The pressurized can (aerosol bomb), as illustrated in Figure 20.1, represents the first type of hand-held sprayer. The can holds pesticide and compressed gas. When the can is set off, the gas and pesticide are forced through the nozzle and become an aerosol. Most pressurized cans hold less than one quart or one liter.

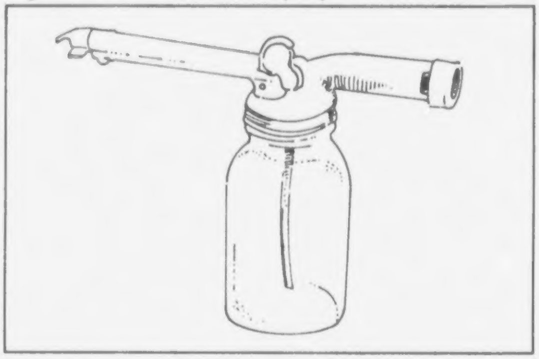
Figure 20.2 illustrates a trigger pump sprayer. When the trigger is squeezed, pressure is built up inside the sprayer causing the pesticide to be driven through the sprayer. Most trigger pump sprayers hold from one pint to one gallon of pesticide mixture.

Figure 20.2 - Trigger Pump



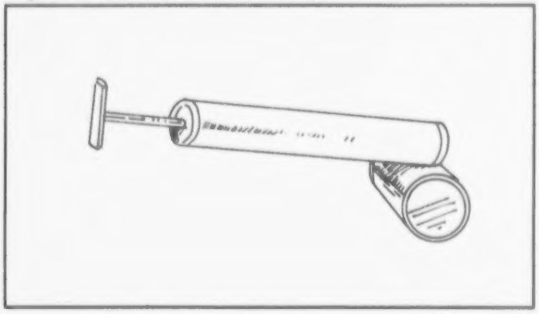
The hose end sprayer device, illustrated in Figure 20.3, holds pesticide concentrate. This concentrate mixes with water coming through the hose so that many gallons of pesticide spray solution may be applied to the plants before the container attached to the end of the hose needs refilling with pesticide concentrate. Therefore, the hose end sprayer device delivers a certain fixed amount of pesticide. Most hose end sprayer devices hold one quart or one liter of pesticide concentrate, which delivers approximately 15 gallons of diluted

Figure 20.3 - Hose End Sprayer Device



pesticide solution. A hose siphon proportioned injector is frequently the type of hose end device utilized for applying fungicides.

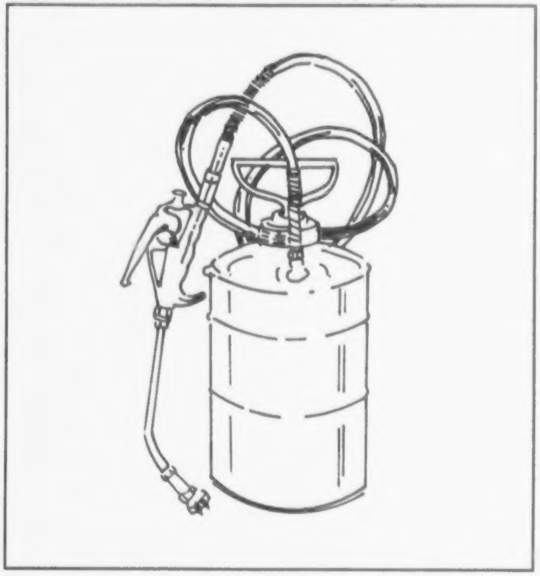
Figure 20.4 - Push-Pull Pump



The push-pull pump sprayer works by a hand-operated plunger, which creates a vacuum in the sprayer container. See Figure 20.4. The push-pull pumping action applies pesticide to plants. Since it is ineffective in applying pesticide with force, it is hard to get adequate coverage of plants. Therefore this type of sprayer is commonly used in only hobby or small greenhouses. Most push-pull hand pump sprayers hold up to one quart of pesticide solution.

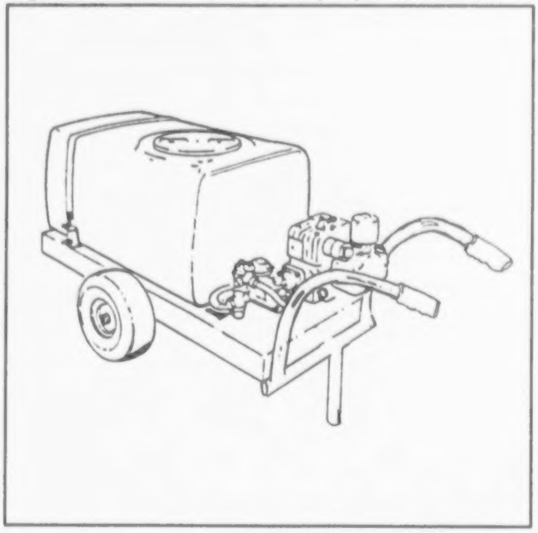
The hand pump compressed air sprayer, illustrated in Figure 20.5, includes a tank with a plunger. One to three gallons of pesticide solution are put into the tank. The plunger is operated to compress the air inside the heavy tank. When the attached trigger is released, the compressed air forces the pesticide from the tank in a fine spray. This type of sprayer is common in small commercial greenhouses and in homes.

Figure 20.5 - Compressed Air Sprayer



Backpack sprayers - A self-contained tank holding the pesticide and a pump are carried on the pesticide applicator's back. This device functions as an enlarged version of a compressed air sprayer, although some models may be powered by a small gasoline engine. Most back-pack sprayers hold up to five gallons of pesticide solution. They are frequently used in commercial greenhouses.

Figure 20.6 - Wheelbarrow Sprayer



Wheelbarrow sprayers - These large capacity sprayers are often used in large commercial greenhouses, because they are mounted on wheels and are easy to move about while containing large amounts of pesticide. See Figure 20.6. The pump on these sprayers may be driven by either gasoline or electrically powered engines. This type of sprayer allows the pesticide applicator great freedom of movement because it comes with 25 feet of hose. Also, the sprayer delivers pesticide under high pressure, therefore enabling the applicator to achieve better coverage of plants. This sprayer is available in many sizes and capacities of delivery. The holding tank may hold up to 50 gallons in larger models.

Aerosol generators and foggers - Aerosol generators and foggers fill the entire closed greenhouse with a pesticide fog or mist. The first type of aerosol generator is a cold fogger in which the pesticide is broken into mist particles by mechanical means (i.e., very fine nozzles and high pressure). The second type of aerosol generator is the thermal generator or thermal fogger, which uses heat to vaporize the pesticide into a smoke-like fog, thus killing or repelling insects.

Formulations of Pesticides

Pesticides are available in various formulations or preparations. However, all pesticides include active ingredients (i.e., killing agents) and an even greater amount of inert ingredients (i.e., agents which carry the active ingredients and which facilitate their application). Liquid formulations and dry formulations are the two main types of pesticide preparations. The pesticide label frequently indicates the type of formulation by a letter that corresponds to a specific formulation. In Figure 20.7 "WP" indicates that it is a wettable powder.

Figure 20.7 - Pesticide Label

Miticide II

10WP Miticide II

Active Ingredients	10%
Inert Ingredients	90%

KEEP OUT OF THE REACH OF CHILDREN

WARNING

*See back label for additional warnings and precautions.

Insecticide Co., Anytown, USA

Liquid formulations - In the commercial greenhouse, the most commonly-used liquid pesticide formulations are aerosols, emulsifiable concentrates, encapsulated insecticides, and flowables. Aerosol pesticides, which are denoted by the letter "A" on the label, are usually sold in pressurized cans or aerosol bombs. The pesticide is released from the can as a fine spray or mist.

Emulsifiable concentrates (denoted by "EC" on the label) are concentrated pesticides dissolved in organic solvents, which are mixed with water in the pesticide spray tank. Encapsulated insecticides contain insecticide particles that are enclosed within very small plastic capsules called microcapsules. These microcapsules are often marketed in an aerosol spray can containing 16 ounces of insecticide. Over a two-week period, the insecticide is released through microscopic holes in the walls of the microcapsules, thus killing and repelling insects.

Flowable insecticides (denoted by "F" or "L" on the label) pour readily and mix easily with water in the pesticide spray tank. Besides being easy to measure and mix, flowables do not create pesticide dust when poured, thus making the product safer for the applicator to use.

Dry formulations - Bait, dust, granular, soluble powder, wettable powder, and dry flowable are the six main kinds of dry formulations pesticides commonly used in the commercial floriculture industry. A bait formulation, which is denoted by "B" on the label, contains food or other substance that attracts the pest; this bait is treated with the pesticide. Once the pest eats the pesticide bait, death results. Such baits are frequently used to control snails, slugs, and rodents found in the greenhouse.

A "D" on the label denotes a dust formulation, which is produced by mixing an active pesticide ingredient with inert ingredients. After they are mixed, they are ground into a fine dry dust, which is applied without the addition of water. Insects with chewing mouth parts (e.g., caterpillars) are sometimes treated with dusts. Granular formulations (denoted by "G" on the label) are pesticides that are prepared like dry dust formulations, except the particles or granules are much bigger in size than dust particles. Systemic pesticides are often formulated as granules (e.g., Oxamyl®) for ease of application to the growing medium.

Dry flowable pesticides are formulated as small dust-free granules that readily dissolve in water. They can be poured like a liquid yet have advantages of a powder (e.g., reduced risk of phytotoxicity).

Soluble powders (denoted by "S" or "SP" on the label) contain an active ingredient that mixes with water in the pesticide spray tank. Wettable powders (denoted by "W" or "WP" on the label) are prepared like dry dust formulations, except they are designed to mix with water. Once mixed with water, wettable powders require constant agitation in the spray tank to keep the pesticide particles in suspension.

Mode of Action for Different Pesticides

Pesticides work in different ways. Many synthetic pesticides work in more than one way. The pesticide label tells how the pesticide works. Biologicals are pesticides that contain living microorganisms such as viruses, bacteria, and fungi. Once the pest eats these pesticides from the host, the pest contracts a disease and dies. Contact poisons kill pests when pests come into contact with them.

Fumigants kill when inhaled or otherwise absorbed by the pest. Growth regulators, when applied to insects, prevent immature insects from reaching adulthood. Nonselective herbicides, when applied at an adequate rate, kill all plants present. Pheromones affect pests by attracting them to traps where they are killed. Protectants are applied to structures, animals, plants and/or products to prevent entry or damage by a pest. Selective herbicides are used to kill target weeds without killing nearby plants. Sterilants make pests unable to reproduce.

Stomach poisons kill when swallowed. Systemics are absorbed by the host plant and translocated to all of its parts. The pest that sucks sap from the host plant will be killed.

Information for Pesticide Recommendations

Because pesticides are constantly being added and withdrawn from the market, it is impossible to give pesticide recommendations that would remain current over time. Therefore, greenhouse operators need to know where they can find up-to-date pesticide recommendations for greenhouse pests. The greenhouse operator could check with the local University Extension Office, with pesticide dealers, or with the Missouri Department of Agriculture.

Summary

Although there are many methods available to control pests, the most commonly-used method in the commercial greenhouse is chemical pesticides. Various techniques and pieces of equipment are used in the greenhouse for pesticide application. Although wettable powder is the most common pesticide formulation used in commercial greenhouses, many formulations are available. In choosing a pesticide, it is important to know the mode of killing action. Whenever handling or applying any pesticide, always follow pesticide label instructions exactly.

Credits

Tayama, Harry K., ed. Insect and Mite Control, Disease Control, and Growth Regulator Booklet. No. 687. Edwardsville, IL: Florists' Mutual Insurance Co., January, 1987.

U.S. Department of Agriculture and U.S. Environmental Protection Agency. Applying Pesticides Correctly, A Guide for Private and Commercial Applicators. U.S. Department of Agriculture and U.S. Environmental Protection Agency.

It is very important to ALWAYS read and follow label directions when using with pesticides.

Pesticide Toxicity

Toxicity levels were established by the Federal Insecticide, Fungicide, and Rodenticide Act, which was amended by the Federal Environmental Pesticide Control Act of 1972. This legislation regulates pesticide use, manufacture, registration, and transportation. The Missouri Pesticide Act meets these federal guidelines.

Pesticide toxicity is measured by the classic LD50 Test. The "LD" stands for "lethal dose" or the amount of the chemical, expressed in milligrams per kilogram of body weight, necessary to kill half of the test population. The lower the LD number, the greater the chemical toxicity and the less it takes to kill. For example, a pesticide with an LD50 rating of 5 would be much more poisonous than a pesticide with a LD50 rating of 300.

Pesticide Label Information

The pesticide label contains important information. Always read and follow label directions exactly. By reading the pesticide label, the individual will be able to determine the type of pesticide being used, the target pest or pests, application techniques, disposal methods, first aid procedures, plants that the pesticide can be used on, and signal words. See Figure 21.1. It is unlawful to use a pesticide in any manner or for any purpose other than those specified on its label. Signal words, which indicate the level of toxicity, are located on the front panel of pesticide labels just below the "KEEP OUT OF THE REACH OF CHILDREN" statement. There are three categories of signal words.

Class I pesticides are labeled "DANGER" or "DANGER-POISON" with an accompanying drawing of a skull and crossbones. The letters are printed in red. Pesticides belonging to this category are extremely toxic when taken into the body through the mouth, through the skin and/or through breathing. In addition, Class I pesticides will cause severe eye and skin burning. Pesticides in Class I have an oral LD50 rating of 0-50. Some of the Class I pesticides are so highly poisonous that even a taste could kill an adult human.

The signal word "WARNING" is on all Class II pesticides. Pesticides in this category are moderately poisonous to humans and have an oral LD50 rating of 50-500. As little as a teaspoon taken by mouth of some of these pesticides could be lethal.

Class III pesticides contain the signal word "CAUTION." These pesticides are slightly toxic to humans and have an oral LD50 rating of 500-5,000. As little as an ounce of certain of these chemicals taken internally could be fatal.

The pesticide label also contains warning statements such as "fatal if swallowed" or "may irritate eyes, nose, throat, or skin." These warning statements are meant to get your attention, not to indicate the only method of entry for the pesticide. Many pesticides could be harmful to the body if any contact is made. It is crucial to wear proper protective clothing whenever applying pesticides in the greenhouse.

Symptoms of Pesticide Poisoning

There are no standard symptoms of pesticide poisoning, since different pesticides affect people differently. Also, symptoms will vary depending on the type of pesticide, amount and length of exposure, the time interval between exposures, and the general health of the victim.

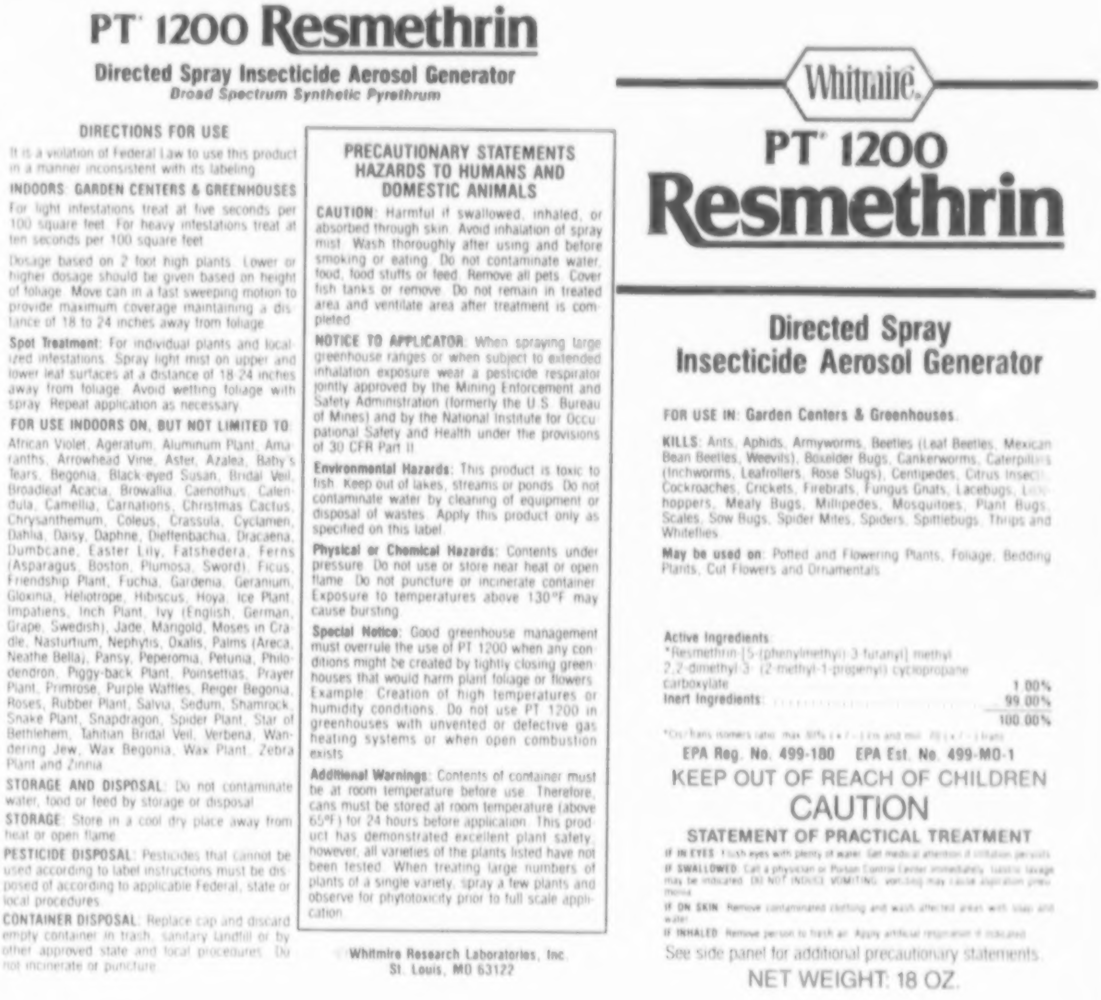
Pesticides may be divided into external irritants, internal poisons, or a combination of both. External irritant pesticides, when splashed on the skin or external body tissues (i.e., eyes, ears, mouth), may cause local swelling, stinging, redness, blisters, and/or rash. In contrast, internal poisoning pesticides when swallowed, inhaled, or absorbed through the skin, may cause such symptoms as headache, nausea, vomiting, and diarrhea. Some pesticides cause both external irritation and internal poisoning simultaneously.

Often pesticide poisoning symptoms are similar to symptoms of other illnesses such as the flu. Yet it is unwise to assume that flu medicine will relieve these symptoms as they may make pesticide poisoning much worse. Therefore, it is important to consult a physician who can diagnose the difference and thus prescribe proper treatment.

First Aid Procedures for Pesticide Poisoning

Since the amount of time elapsing between the pesticide poisoning and getting to the doctor may make the difference between life and death for the poisoning victim, ALWAYS ACT IMMEDIATELY. Without endangering yourself, remove the victim from the contaminated area. Remove contaminated clothing from the victim. In order to protect

Figure 21.1 - Pesicide Label



PT* 1200 Resmethrin

Directed Spray Insecticide Aerosol Generator

Broad Spectrum Synthetic Pyrethrum

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

INDOORS: GARDEN CENTERS & GREENHOUSES

For light infestations treat at five seconds per 100 square feet. For heavy infestations treat at ten seconds per 100 square feet.

Dosage based on 2 foot high plants. Lower or higher dosage should be given based on height of foliage. Move can in a fast sweeping motion to provide maximum coverage maintaining a distance of 18 to 24 inches away from foliage.

Spot Treatment: For individual plants and localized infestations. Spray light mist on upper and lower leaf surfaces at a distance of 18-24 inches away from foliage. Avoid wetting foliage with spray. Repeat application as necessary.

FOR USE INDOORS ON, BUT NOT LIMITED TO:

African Violet, Ageratum, Aluminum Plant, Amaranths, Arrowhead Vine, Aster, Azalea, Baby's Tears, Begonia, Black-eyed Susan, Bridal Veil, Broadleaf Acacia, Browallia, Caenothus, Calendula, Camellia, Carnations, Christmas Cactus, Chrysanthemum, Coleus, Crassula, Cyclamen, Dahlia, Daisy, Daphne, Dieffenbachia, Dracaena, Dumbcane, Easter Lily, Fatshedera, Ferns (Asparagus, Boston, Plumosa, Sword), Ficus, Friendship Plant, Fuchia, Gardenia, Geranium, Gloxinia, Heliotrope, Hibiscus, Hoya, Ice Plant, Impatiens, Inch Plant, Ivy (English, German, Grape, Swedish), Jade, Marigold, Moses in Cradle, Nasturtium, Nephytis, Oxalis, Palms (Areca, Neathe Bella), Pansy, Peperomia, Petunia, Philodendron, Piggy-back Plant, Poinsettias, Prayer Plant, Primrose, Purple Waffles, Reiger Begonia, Roses, Rubber Plant, Salvia, Sedum, Shamrock, Snake Plant, Snapdragon, Spider Plant, Star of Bethlehem, Tahitian Bridal Veil, Verbena, Wandering Jew, Wax Begonia, Wax Plant, Zebra Plant and Zinnia.

STORAGE AND DISPOSAL: Do not contaminate water, food or feed by storage or disposal.

STORAGE: Store in a cool dry place away from heat or open flame.

PESTICIDE DISPOSAL: Pesticides that cannot be used according to label instructions must be disposed of according to applicable Federal, state or local procedures.

CONTAINER DISPOSAL: Replace cap and discard empty container in trash, sanitary landfill or by other approved state and local procedures. Do not incinerate or puncture.

PRECAUTIONARY STATEMENTS HAZARDS TO HUMANS AND DOMESTIC ANIMALS

CAUTION: Harmful if swallowed, inhaled, or absorbed through skin. Avoid inhalation of spray mist. Wash thoroughly after using and before smoking or eating. Do not contaminate water, food, food stuffs or feed. Remove all pets. Cover fish tanks or remove. Do not remain in treated area and ventilate area after treatment is completed.

NOTICE TO APPLICATOR: When spraying large greenhouse ranges or when subject to extended inhalation exposure wear a pesticide respirator jointly approved by the Mining Enforcement and Safety Administration (formerly the U.S. Bureau of Mines) and by the National Institute for Occupational Safety and Health under the provisions of 30 CFR Part II.

Environmental Hazards: This product is toxic to fish. Keep out of lakes, streams or ponds. Do not contaminate water by cleaning of equipment or disposal of wastes. Apply this product only as specified on this label.

Physical or Chemical Hazards: Contents under pressure. Do not use or store near heat or open flame. Do not puncture or incinerate container. Exposure to temperatures above 130°F may cause bursting.

Special Notice: Good greenhouse management must overrule the use of PT 1200 when any conditions might be created by tightly closing greenhouses that would harm plant foliage or flowers. Example: Creation of high temperatures or humidity conditions. Do not use PT 1200 in greenhouses with unvented or defective gas heating systems or when open combustion exists.

Additional Warnings: Contents of container must be at room temperature before use. Therefore, cans must be stored at room temperature (above 65°F) for 24 hours before application. This product has demonstrated excellent plant safety, however, all varieties of the plants listed have not been tested. When treating large numbers of plants of a single variety, spray a few plants and observe for phytotoxicity prior to full scale application.

Whitmire Research Laboratories, Inc.
St. Louis, MO 63122

Whitmire.

PT* 1200 Resmethrin

Directed Spray Insecticide Aerosol Generator

FOR USE IN: **Garden Centers & Greenhouses**.

KILLS: Ants, Aphids, Armyworms, Beetles (Leaf Beetles, Mexican Bean Beetles, Weevils), Boxelder Bugs, Cankerworms, Caterpillars (Inchworms, Leafrollers, Rose Slugs), Centipedes, Citrus Insects, Cockroaches, Crickets, Firebrats, Fungus Gnats, Lacebugs, Leafhoppers, Mealy Bugs, Millipedes, Mosquitoes, Plant Bugs, Scales, Sow Bugs, Spider Mites, Spiders, Spittlebugs, Thrips and Whiteflies.

May be used on: Potted and Flowering Plants, Foliage, Bedding Plants, Cut Flowers and Ornamentals.

Active Ingredients: *Resmethrin-[5-(phenylmethyl)-3-furanyl] methyl 2,2-dimethyl-3- (2-methyl-1-propenyl) cyclopropane carboxylate	1.00%
Inert Ingredients:	99.00%
	100.00%

*Cis/Trans isomers ratio: max. 30% (+/-) cis and min. 70% (+/-) trans

EPA Reg. No. 499-180 EPA Est. No. 499-MO-1

KEEP OUT OF REACH OF CHILDREN

CAUTION

STATEMENT OF PRACTICAL TREATMENT

IF IN EYES: Flush eyes with plenty of water. Get medical attention if irritation persists.

IF SWALLOWED: Call a physician or Poison Control Center immediately. Gastric lavage may be indicated. DO NOT INDUCE VOMITING: vomiting may cause aspiration pneumonia.

IF ON SKIN: Remove contaminated clothing and wash affected areas with soap and water.

IF INHALED: Remove person to fresh air. Apply artificial respiration if indicated.

See side panel for additional precautionary statements.

NET WEIGHT: 18 OZ.

Credit: Whitmire Research Laboratories, Inc., St. Louis, MO 63122.

yourself from contamination, wear protective clothing and/or equipment. Generously flood the affected area with water. Contact the Poison Control Center or a doctor and administer first aid procedures as indicated.

Nearest Poison Control Center

When seeking medical assistance for a case of pesticide poisoning, quick and calm action is extremely important. The Poison Control Center number should be located by the phone for easy access. In Missouri, this facility is staffed 24 hours a day by medical professionals. These professionals will ask questions about the victim and about the pesticide. It is important to have the pesticide label or container close by when contacting the center.

The statewide center may refer callers to a local hospital specially equipped to treat poisoning emergencies. Information about Missouri's statewide center and its toll-free number follows:

Missouri Regional Poison Control Center
Cardinal Glennon Memorial Hospital
1465 South Grand Avenue
St. Louis, Missouri 63104
Telephone: 1-800-392-9111

First Aid Kit

Every greenhouse should have first aid supplies on hand. The container for the first aid supplies should keep the supplies clean and should be easily accessible. A first aid kit could be purchased or the greenhouse manager could make one containing at least the following items.

1. Adhesive tape
2. Assorted adhesive and gauze bandages
3. Blanket - enclosed in plastic to keep clean and dry
4. Merthiolate
5. Syrup of ipecac
6. Teaspoon
7. Two quarters - taped to the inside cover of the first aid kit for phone calls

Safety Guidelines for Using Pesticides

Since pesticides may be absorbed (through the skin, eyes, and ears), inhaled, and/or swallowed, it is important to follow safety guidelines to prevent pesticide poisoning. First and foremost, always read and follow pesticide label directions exactly. Label directions will not only indicate application procedures, but preharvest interval and safe reentry time as well. The preharvest interval is the time interval required between applying the pesticide and the safe harvest date of the crop for human consumption. Before applying any pesticide, remove all people, pets, and foodstuffs from the greenhouse. Close all doors, vents, and openings in the greenhouse to avoid pesticide drift. Pesticide drift is when the pesticide tends to drift away from the target area. Never smoke, eat, or drink when applying pesticides.

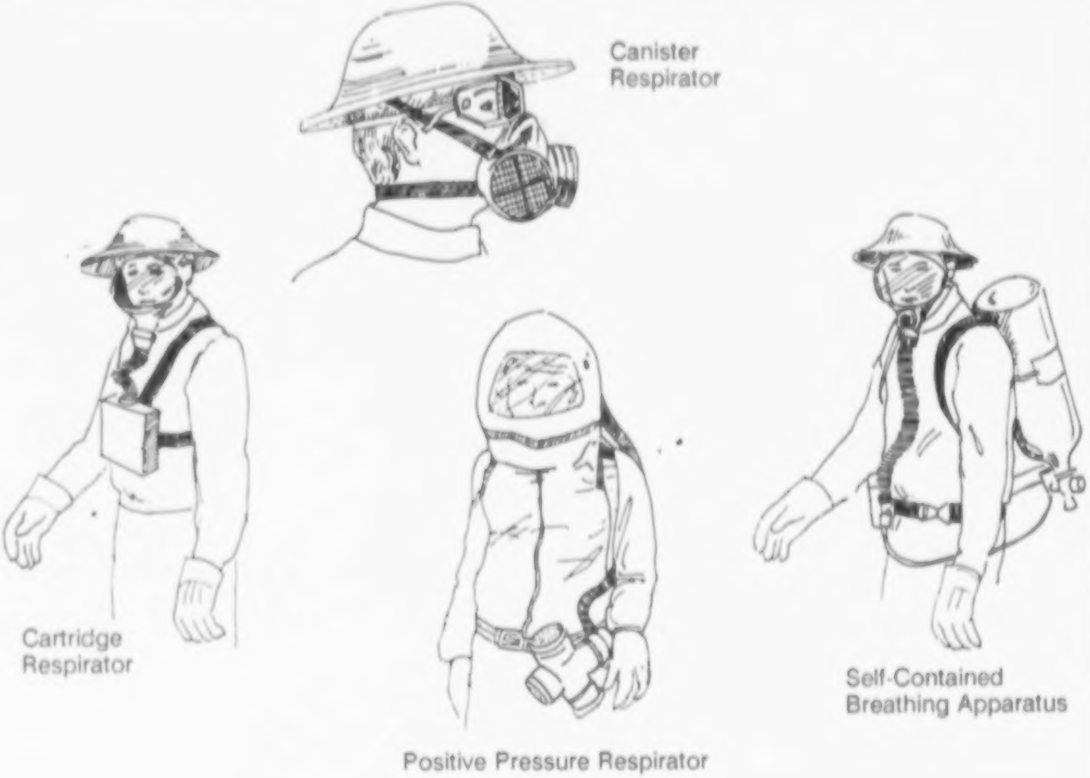
Always wear protective clothing and use protective equipment to prevent exposure to external irritant pesticides. Wear clean long trousers and a long-sleeved shirt or coveralls made of closely woven cloth. Wear unlined rubber gloves and rubber boots made of neoprene. Wear shirt sleeves outside of the gloves and wear pant legs outside of the boots to prevent pesticides from entering. Wear close-fitting eye goggles or a face shield. It is recommended that the pesticide applicator wear a wide-brimmed waterproof hat, one that is easy to clean or is disposable.

The applicator should always wear a respiratory device that prevents internal poisoning whenever applying a pesticide. Be sure that every respirator carries a seal of approval for pesticide use from the National Institute for Occupational Safety and Health (NIOSH) as well as from the Mine Safety and Health Administration (MSHA). Carefully read the accompanying instructions for the use and care of each respirator. There are several types that could be used depending on the pesticide used, the length of exposure, and the frequency of exposure. See Figure 21.2.

The first type is a cartridge respirator, a mask that covers the mouth and nose; it is tightly sealed to the face. It should be used in combination with eye-protecting goggles. With this device, incoming air is drawn through a fiber filter pad and a charcoal cartridge by normal breathing for the purpose of absorbing pesticide vapors. Thus, most pesticide particles are removed before reaching the nose and mouth. A cartridge respirator is satisfactory for occasional exposure to most pesticides. However, always consult the pesticide label for exact precautions.

The second type of respiratory device is a gas mask (canister respirator), which should be worn when the applicator encounters prolonged pesticide exposure or is exposed to high concentrations of pesticides for short time periods. Such a gas mask usually covers the entire face with a

Figure 21.2 - Types of Respirators



built in shield to protect the eyes and is tightly sealed around the face. It has longer-lasting absorbent filters than does a cartridge respirator. Also, the filtering capability of a canister respirator is greater than that of a cartridge respirator.

The cartridges and canisters of these two respirators must be replaced on a regular basis. If the applicator smells the pesticide or has trouble breathing while wearing the respiratory device, stop immediately and change the absorbing cartridge, canister, or filter. Then throw out the used cartridge, canister, or filter.

Another type of respiratory device is a positive pressure respirator, which is available as a small backpack. A lightweight blower draws the pesticide-laden air through a filter and then forces the cleaned air into an airtight helmet covering the entire head and neck.

If the oxygen supply is low or the pesticide vapor concentration is high, neither the cartridge respirator nor the gas mask offer adequate protection. In these instances, the pesticide applicator must use a self-contained breathing apparatus. When using a self-contained breathing apparatus, the applicator carries air tanks along, usually on his/her back. This type of device requires special training for proper use.

Fumigant pesticides quickly become gases, which pose a great threat of injury or death by inhalation to pesticide applicators. Therefore, for fumigant pesticides, always use a self-contained breathing apparatus, both when applying the pesticide and upon re-entry into the treated site after fumigation.

After applying pesticides, remove clothing and take a shower with plenty of soapy water; shampoo and rinse the hair well. Launder pesticide-laden clothing separately from other clothing. If disposable clothing is worn, dispose of properly.

When applying pesticides on a continuing basis, it is wise to establish a health surveillance program with a physician. Inform the doctor about the identity of the pesticides used. Then the doctor can review the chemical formulations, poisoning symptoms, and treatments. In addition, the physician can stock a supply of the necessary antidotes. Since no drugs work to prevent pesticide poisoning, it is wise to be prepared in case it may occur.

Applicators who regularly work with carbamate or organophosphate insecticides should set up a regular cholinesterase testing program with their physicians. Cholinesterase is a biological enzyme that is part of the body's nervous system. Carbamate and organophosphate insecticides can cause serious health hazards by interfering with the availability of cholinesterase. Therefore, the doctor should perform a cholinesterase test in January to establish a "base line level" for each applicator. Then periodic re-tests must be taken to check cholinesterase levels. If the applicator's cholinesterase level falls too low, then the doctor will limit or stop the patient's contact with these two types of insecticides.

Disposal of Pesticides and Pesticide Containers

Try to mix the correct amount of pesticide solution for each application to avoid the need to dispose of the excess amount. Excess prepared pesticides must be disposed of safely to avoid harming people, animals, or the environment. First, carefully read and follow pesticide container label instructions for precautions and/or disposal methods. If additional areas have the same pest problem, apply the surplus pesticide on those areas as well. If this is impossible, then take the excess pesticide and/or pesticide containers to a landfill operating under a supplemental permit allowing for toxic waste disposal. The same should be done for outdated or unwanted pesticides. Note that a great majority of solid waste landfills lack a supplemental permit and, consequently, are not legally able to handle pesticides. Never flush pesticides down the drain or into sewers. Federal rules require that organic pesticides be disposed of by burial or by burning.

Do not leave pesticides or pesticide containers at the application site. Never reuse pesticide containers. Keep all pesticide containers out of the reach of children. Leftover pesticides should be kept in tightly closed containers in a storage facility. The U.S. Department of Agriculture and the U.S. Environmental Protection Agency has set up specific guidelines for pesticide disposal. The State of Missouri Department of Natural Resources can help with problems concerning the safe disposal of pesticides and pesticide containers. The address and phone numbers follow:

Missouri Department of Natural Resources
Division of Environmental Quality
P.O. Box 176
Jefferson City, MO 65102
Business phone: (314)751-7929
Emergency response phone: (314)634-2436

Pesticide Certifications

Regarding certification, it should be noted that pesticides may be 100 percent general use or 100 percent restricted use or a mixture of the two (based upon the exact nature of the use). This information will be clearly stated on the label of the pesticide container. A general use pesticide is defined as one not likely to harm people, wildlife, and/or the environment when used according to label instructions. Some examples of general use pesticides, which are often used on greenhouse-grown crops, are: Malathion®, Talstar®, and Benlate®. Certification is not required in order to apply general use pesticides.

In contrast, a restricted use pesticide could cause serious injury to people, wildlife, or the environment unless it is applied by a well-trained and competent certified pesticide applicator or under his or her direct supervision. Therefore, certification is required for handling restricted use pesticides. Some examples of restricted use pesticides commonly used in floriculture are: Lannate®, Vydate®, and Di-Syston®.

Pesticide certification is granted to people who undergo special instruction set up by the State of Missouri Department of Agriculture Plant Industries Division. The actual educational materials and training sessions are provided by the University of Missouri Extension Division. The U.S. Environmental Protection Agency (EPA) oversees Missouri's certification program. After completing the instructional process, applicants must then pass a competency test in the safe handling and use of pesticides. Finally, a license is issued to each person successfully completing the pesticide training session.

There are two main categories of certified pesticide applicator licenses: private applicator and commercial applicator. Private applicators administer restricted use pesticides onto their own land, onto land they rent, or onto the property of another person with whom they trade services.

Most horticulturists are private applicators. A certified private pesticide applicator's license is valid for five years and then must be renewed.

Commercial applicators apply restricted use pesticides for hire on the property of others. Commercial applicators are trained and tested like private applicators, but receive additional instruction in various areas of pesticide application specialization. Some examples of possible area of pesticide application specialization are: ornamental and turf pest control, seed treatment, and forest pest control. A certified commercial pesticide applicator's license is valid for three years and then must be renewed.

Summary

To avoid toxic chemical injury to humans, animals, and/or the environment, it is crucial to read and follow all label directions for the pesticide being applied. Appropriate clothing and protective equipment should be worn when applying pesticides in the greenhouse. Depending on the pesticides to be applied, the applicator may be required to have a certified pesticide applicator's license.

Credits

Nelson, Paul V. Greenhouse Operation and Management. 3rd ed. Reston, VA: Reston Publishing Co., Inc., 1978.

U.S. Department of Agriculture and U.S. Environmental Protection Agency. Applying Pesticides Correctly, A Guide for Private and Commercial Applicators. U.S. Department of Agriculture and U.S. Environmental Protection Agency, n.d.

University Extension agricultural publications, University of Missouri-Columbia:

1) GO1915: First Aid for Pesticide Poisoning
2) GO1916: Pesticide Application Safety
3) GO1917: Personal Protective Equipment for Working with Pesticides
4) GO1918: Homeowner Chemical Safety

Even though greenhouse growers may start their business because of a love of plants, they also want to make money. In order to make a profit, a grower not only needs to be able to grow quality plants, but must be able to market those plants.

Potential Markets for Greenhouse Crops

The potential markets for greenhouse crops are extensive. Usually a grower will look to local markets first as this will be more cost effective as far as transportation costs are concerned. A marketing plan is absolutely essential, otherwise the grower could end up with a greenhouse full of crops and nowhere to sell them. A potential grower would be well-advised to talk to several prospective buyers and find out what kind of plants they want to sell and during what season. Equally important is the price they are willing to pay. Another good source of marketing ideas is experienced growers in your area as well as horticultural supplies salespeople.

The two major ways of selling greenhouse crops are wholesale and retail. Wholesale is selling to a business that will sell the crop to the person using it. Possible wholesale opportunities include: other wholesalers, local grocery stores, local florists, chain discount stores, hardware stores, and local organizations (on a consignment basis). Retail is selling to the person that will be using the crop. The retail greenhouse owner may sell out of his or her greenhouse or at farmers' markets. There are advantages and disadvantages to both. Many greenhouse owners sell at wholesale and retail levels.

Wholesale - One advantage to selling wholesale is that the grower can usually sell the entire crop all at one time. There isn't a need to advertise or hire salespeople to wait on customers. It isn't necessary to keep the business open for longer hours or on weekends. The wholesale manager doesn't have to deal with customers' complaints.

The main disadvantage of selling wholesale is that the manager has a lower return per crop unit. The manager also may have to purchase additional equipment (e.g., delivery vehicles). In addition, marketing may be more competitive due to other greenhouses shipping plants into the market area.

Retail - The main advantage of selling retail is the grower receives a higher return per crop unit. The retailer may develop a more reliable market due to repeat customers. There is not a need to purchase expensive marketing equipment (e.g., large delivery vehicles). Also, there is the personal reward from seeing satisfied customers.

One of the disadvantages of the retail greenhouse business, is that the greenhouse must be designed to accommodate customers, thereby lowering benching efficiency. Also, support facilities (e.g., parking) are required. The retail greenhouse is more labor intensive, because additional salespeople are required. In addition, there is competition from low-priced products in mass marketing outlets (e.g., chain stores), which may jeopardize the operation.

Maintaining Plant Quality During the Marketing Process

Toning or hardening a potted plant crop by growing it on the "dry side" for 7-10 days before it is ready to be sold is essential for longevity in the consumer's home environment. Greenhouse temperatures are also reduced by several degrees during the toning process. Reducing or eliminating fertilizer during its toning period also helps to develop a harder, less succulent plant that will hold up well in the marketing process. Additionally, several crops require specific cultural practices which will produce a plant that will last longer and increase customer satisfaction.

Poinsettias

1. Harvest plants when mature (full color development).
2. Plants should be thoroughly watered before shipping.
3. If plants must be held prior to shipping, hold unsleeved and/or unboxed in the greenhouse or other well-lighted area between 50°F (10°C) and 75°F (24°C).
4. Protect plants during shipping using boxes and plastic sleeves.
5. Avoid extreme temperatures. Temperatures above 75°F (24°C) or below 50°F (10°C) during shipping and marketing shorten post-production life.
6. Careful handling is required to prevent plant breakage.
7. Avoid exposure to ethylene or other gases which may be harmful to the plant.
8. During shipping, keep bracts dry to reduce the possibility of botrytis (gray mold).
9. When received by the retailer, plants should be unpacked as soon as possible to reduce or prevent epinasty (droopiness). Poinsettias are especially susceptible to this condition.

10. Display plants in a well-lighted area between 50°F (10°C) and 75°F (24°C) away from hot or cold drafts.

Chrysanthemums

1. Harvest when plants are mature (1/2 to fully open).
2. Remove from packing box immediately upon arrival and water plants thoroughly.
3. Remove all broken stems and blooms.
4. Be sure that the mums are displayed with plenty of room so that they receive the best amount of light.
5. Keep the plants out of direct sun.
6. Make sure that they do not sit in a hot or cold draft.
7. Do not keep the plants too wet - allow them to dry out between waterings but not to the wilting point.

Easter lilies - Since temperature plays an important part in the blooming of Easter lilies, the only time it would be beneficial to drop the temperature would be if the lilies start to bloom too soon before Easter. If necessary, it is possible to hold Easter lilies in the dark at 35°F (2°C) to 45°F (7°C) when the buds are white and puffy for up to 20 days. The soil should be kept moist and a fungicide should be applied as a drench 10 days before the lilies are put into storage.

Bedding plants - Some growers recommend water stressing bedding plants a few days before they are to be sold. The grower should avoid allowing the plants to wilt too much. It is also recommended to drop the temperature to 55°F (13°C) the last several weeks. Fertilizer is also reduced and in some cases eliminated entirely in the last several weeks before sale.

Preparing a Plant for Sale

Grooming a plant is the first step in preparing it for sale, whether the grower is intending to retail it out of the greenhouse or sell it to one of the wholesale outlets. Remove all yellow or dying leaves as well as old flowers. These not only look ugly, but can also encourage disease. If the pot is dirty, a quick wipe of the outside with a paper towel will help. Check the plant for any insect pests.

A plant should never be sold with insects on it. Several suppliers will have care tags. These contain valuable information about the plant. The customer may forget verbal care instructions, but a care tag in the pot will be a quick reference.

Once the plant is properly groomed and in good condition to be sold, retailers will "dress" a plant by wrapping the pot in foil and ribbon. Florist's foil is either polyfoil (two pieces of foil bonded together) or single foil. Polyfoil is much more durable and won't tear apart easily. Single foil is easier to shape to the sides of the pot, but is very fragile and will tear if care is not taken in handling it.

The color of the foil and the ribbon should complement the flower of the potted plant. Cut the foil to the appropriate size for the pot (e.g., 26 inches for a six-inch pot). Some florists fold down the edges of the foil 2-3 inches on all four sides. If this method is used, additional foil will need to be used. Place the pot on the foil slightly to the front, positioning the plant so its best side is toward you. Make sure that the front will come up and cover the pot. With your left hand, work around the left side of the plant, gently gathering the foil up and around the pot. With your right hand, gently pull the corners upward as you work around the pot. After you have gathered the foil around the pot, curve the two front corners downward so that they form a frame around the front. Make a bow from either #40 or #9 ribbon. Tie it off with a wired wooden pick. Insert the pick in the growing medium in the front of the pot. Some florists will wrap a length of ribbon from the top of the pot, down the side, under the back and back up the other side, securing it in the top with the pick.

Summary

Greenhouse growers need to know how to market their crop to receive a profit and stay in business. Every grower must also know how to handle a crop to ensure its lasting quality for a satisfied consumer. Preparing a plant for sale will ensure the plant to be the most attractive it can be, thus ensuring its salability.

Credits

Ball, Vic, ed.; Geo. J. Ball Inc. Ball Red Book-Greenhouse Growing. Reston, VA: Reston Publishing Co., Inc. (A Prentice-Hall Co.), 1985.

Larson, Roy A., ed. Introduction to Floriculture. New York: Academic Press, Inc., 1980.

Rothenberger, Ray. "Care of Several Flowering Potted Plants I," Grounds for Gardening. #GO6511. University of Missouri-Columbia: University Extension.

Kaczperski, Mark, et al. Post-Production Damage of Poinsettias. North Central Regional Publication No. 268. Cooperative Extension Service, Michigan State University.

Lesson 23: Record Keeping in Greenhouse Management

The production of greenhouse crops is an extremely competitive business. Any business that does not keep accurate records is likely to fail, for it will make the same mistakes time and time again. Records are also required for legal reasons such as paying taxes. Additionally, planning the rotation of greenhouse crops to make optimum utilization of available space is necessary if a greenhouse business is to achieve maximum profits.

Cultural Records

Cultural records are kept to provide the basis needed in order to duplicate a successful crop. Also, cultural records can be helpful in pinpointing the cause of crop failures, and correcting the cause before the production of the next crop. Before any crop is planted, a cultural schedule (Figure 23.1) should be prepared. The culture schedule should include all of the operations to be performed on the crop (e.g., planting, fertilizing, temperature and day length control, pest control) and the date each operation is to be performed. Also, record on the schedule in the space provided the date each operation was accomplished and by whom. The manager can initial each operation to verify that it has been done.

The cultural schedule should be kept in the greenhouse manager's office. A duplicate schedule is kept at the location (e.g., bench or bed) of each crop. When an operation on the sheet is performed, the date and the name of the employee performing the work should be

Figure 23.1 - Typical Cultural Schedule

Greenhouse Section	Benches	Crop	Cultivar
X	1-5	Pot Mums	Bright Golden Ann

Date Scheduled	Date Accomplished	Operation	Employee	Manager's Initials
2-19		Plant; Begin long days.		
2-26		Begin short days.		
3-5		Pinch		
		Apply B-nine.		
		Disbud.		
4-30		Stop fertilizer application.		
5-7		Harvest.		

A CLF program of 200 ppm N from 10-20-10 peat-lite is in place.
Spray as necessary for pest control.

recorded. Unscheduled operations are also entered on the sheet as they are performed. At the end of each day the greenhouse manager verifies the entries by initialing them. After a crop has been harvested, its cultural schedule is collected and kept with the greenhouse manager's records.

Environmental Records

Since a plant's environment dramatically influences its growth, it is important for the greenhouse manager to maintain a record of the environmental conditions in which a crop was grown. These conditions include temperature (inside and outside the greenhouse), available light, growing medium used, nutrient analysis, foliar analysis, insect and disease occurrence, and other visual observations. Such information helps to monitor environmental control equipment within the greenhouse and better enables the greenhouse manager to determine the cause of a poor crop.

Certain bits of environmental information (e.g., outside temperature and light) are the same for an entire greenhouse operation and usually are available from a local branch of the National Weather Service. A record of daily minimum and maximum temperatures, heating degree days, and solar radiation (available light) should be kept. The winter temperature and heating degree days help to judge if the heating costs of one year will be a good prediction of such costs for future years. Also, the amount of money to allocate for heating costs per crop can be made more accurately, easing the task of cost accounting. Summer temperature data can be likewise useful. A record of solar radiation can give the greenhouse manager a better idea of which environmental factor might have limited plant growth, thereby better enabling him or her to adjust other environmental parameters to their optimum.

Inside temperature, growing media, nutrient analysis, tissue analysis, and pest occurrence are maintained on an individual crop basis. Recording thermometers with a seven-day record show the exact inside temperature for an entire week. For those on a limited budget, a thermometer that shows the minimum and maximum temperatures to which it has been exposed can be used and checked on a daily basis. Periodic nutrient analyses of the growing medium and foliage should be made and retained with the cultural schedules record of each crop. Such analyses can help to pinpoint nutritional problems and allow the greenhouse manager to make appropriate adjustments to the fertilizing program used. Records of insect and disease occurrence should also be kept so that appropriate adjustments can be made in spray schedules designed to prevent these pests.

Crop Rotation Plan

For maximum profits, the greenhouse manager must plan to use space as efficiently as possible. A crop rotation plan should be designed to maximize bench space utilization as long as it does not result in crops of low profitability. The crop rotation plan dictates the crops that are to be grown throughout the course of the year, the amount of space assigned to each crop at every stage of production, and where the crop is to be located in the greenhouse range. See Figure 23.2.

This task is more difficult than what first meets the eye. Maximum space utilization efficiency implies not only that all space be occupied, but that the density of pots (or plants) be optimized. This is done by progressive spacing, which is spacing a crop very close together when newly transplanted followed by progressively giving the plants more space as they mature until a final finishing space is reached. This calls for a crop rotation plan that will have space available from the sale of one crop as a second crop is planted or needs to be given more space. Computer software programs are now available that can help make crop scheduling a less cumbersome task for the greenhouse manager.

Cost Accounting Records in Greenhouse Management

Records that keep track of the cost of and income from a crop are very important. Only through accurate record keeping will a greenhouse manager know which crops are making a profit and which are losing money.

All expenses incurred in the production of a crop must be identified. Most economists divide the expenses of a business into two main categories: fixed costs and variable costs.

Fixed costs - Fixed costs (also called overhead costs) are those costs incurred by the entire greenhouse business and not by one particular crop. Fixed costs are somewhat stable and are incurred whether the greenhouse is operating or not. The main fixed costs are depreciation on greenhouse structures and equipment, taxes,

Figure 23.2 - Example Crop Rotation Plan

TIME-SPACE REQUIREMENTS == GREENHOUSE CROP PLAN == 1987 SORTED BY FINISHING WEEKS

Crop Name	Pot Size	Temp.	No. of Pots	First Space	Second Space	Third Space	Time Seq. A	B	C	Start Week	Sell Week	Week 1	2	3	4	5	Week 6	7	8	9	10	11	12	Total SFW
Totals												7836	8496	8833	10051	9614	8114	6701	6134	7419	8495	9291	9908	86.8%
Hyacinths	6	40	600	0.34			13			37	1													0
African Violets	4	65	400	0.15	0.34	0.56	4	4	4	41	1	224												224
Hyacinths	6	65	600	0.44			3			50	1	264												264
Cyclamen	6	60	400	0.34	0.70	1.36	5	4	4	41	2	544	544											1088
Hyacinths	6	65	600	0.44			3			1	4	264	264	264	264									1056
Hyacinths	6	40	600	0.34			13			40	4													0
Cyclamen	6	60	400	0.34	0.70	1.36	5	4	4	43	4	544	544	544	544									2176
Azalea	6	40	600	1.00			6			44	4													0
Azalea	6	60	600	1.36			6			50	4	816	816	816	816									3264
Narcissus	6	60	600	0.44			2			3	5			264	264	264								792
Narcissus	6	40	600	0.34			16			39	5													0
Rieger Begonias	6	60	400	0.34	0.84	1.36	5	5	5	42	5	544	544	544	544	544								2720
Cyclamen	6	60	600	0.34	0.70	1.36	5	4	4	44	5	420	816	816	816	816								3684
African Violets	4	65	800	0.17	0.44		6	6		45	5	352	352	352	352	352								1760
Tulips	6	65	800	0.44			4			2	6		352	352	352	352	352							1760
Hyacinths	6	65	600	0.44			2			4	6				264	264	264							792
Tulips	6	40	800	0.34			14			40	6													0
Hyacinths	6	40	600	0.34			16			40	6													0
Cineraria	6	50	400	0.34	0.84	1.36	6	6	6	40	6	544	544	544	544	544	544							3264
Azalea	6	40	700	1.00			8			44	6													0
Primulas	4	45	800	0.17	0.25		7	7		44	6	200	200	200	200	200	200							1200
Caladium	6	65	600	0.11	0.11	0.7	4	4		50	6	66	66	66	66	66	66							396
Azalea	6	60	700	1.36			6			52	6	952	952	952	952	952	952							5712
Tulips	6	65	600	0.44			3			4	7				264	264	264	264						1056
Tulips	6	40	600	0.34			16			40	7													0
Cineraria	6	50	400	0.34	0.84	1.36	6	6	6	41	7	336	544	544	544	544	544	544						3600
Kalanchoe	6	65	400	0.34	0.56	1.00	6	6	6	42	8	224	224	400	400	400	400	400	400					2848
Caladium	6	65	400	0.11	0.70					52	8	44	44	44	280	280	280	280	280					1532
Cineraria	6	50	400	0.34	0.84	1.36	6	6	6	41	9	336	336	336	544	544	544	544	544	544				4272
Primula	4	45	400	0.17	0.25		6	6		49	9	68	68	68	100	100	100	100	100	100				804
Caladium	6	65	400	0.11	0.70		4	3		3	10			44	44	44	44	280	280	280	280			1296
Asiatic Lilies	6	55	600	0.34	0.70		6	5		51	10	204	204	204	204	204	420	420	420	420	420			3120
Calceolarias	6	50	400	0.34	0.56	1.00	6	6	5	47	11	224	224	224	224	224	224	400	400	400	400	400		3344
Caladium	6	65	1000	0.11	0.7		4	3		5	12					110	110	110	110	700	700	700	700	3240
Tulips	6	65	600	0.44			3			9	12									264	264	264	264	1056
Tulips	6	40	600	0.34			17			44	12													0
Hydrangea	6	60	400	0.34	0.70	1.36	5	4	4	51	12	136	136	136	136	280	280	280	280	544	544	544	544	3840

insurance, interest on loans, and repairs and maintenance on facilities and equipment. There may be other miscellaneous fixed costs such as salaries of management-level personnel, dues, and accounting fees.

Variable costs - Variable costs (also called direct costs) are those costs that vary with the crop or season and occur because the greenhouse is actually operating. Variable costs include plant materials, cultural supplies (e.g., growing media, fertilizers, pesticides), labor, fuel, utilities, and sales costs (e.g., advertising and marketing expenses). Other miscellaneous variable costs may be incurred.

Income - Income from sales should be recorded on the cost accounting sheet for each crop. The date of sale, market outlet (customer), product grade, number of units sold and price per unit, and total sale should be recorded. Also, include the amount of each crop (if any) that must be "dumped". Dumpage should be separated into good but unwanted plants versus poor and unsalable plants.

Profitability - After costs and income have been determined, a cost analysis statement is prepared to determine the profitability of a crop. Such a statement (Figure 23.3) is prepared for each crop and serves to identify the nature of expenses and sources of income. Fixed expenses are commonly determined by the average amount it costs to operate a square foot of greenhouse space for one week. This figure is calculated by totalling all fixed costs for the year and dividing that number by 52, then dividing that number by the total square feet of bench space. By figuring fixed

Figure 23.3 - Cost Accounting Work Sheet

Crop ____________ Greenhouse Section __________________

EXPENSES

Fixed

Depreciation on facilities and equipment __________
Interest __________
Repairs and maintenance on facilities and equipment __________
Taxes __________
Insurance __________
Miscellaneous __________
Total Fixed ____________

Variable

Plant material __________
Cultural supplies (e.g., growing media, fertilizers) __________
Fuel __________
Utilities __________
Sales costs (e.g., advertising and marketing expenses) __________
Miscellaneous __________
Total Variable ____________

TOTAL EXPENSES ____________

INCOME

Date	Customer	Grade	Units	Unit Price	Total

TOTAL INCOME ____________

PROFIT OR LOSS ____________

costs on a square foot basis, the manager can assign the amount of fixed costs for each crop in the greenhouse.

For example, suppose a chrysanthemum crop occupied 500 square feet of bench space for a period of 12 weeks. If the fixed costs for growing this crop are 25 cents per square foot per week, then the total fixed costs for the above would equal $1,500.

It must be realized when determining the profitability of a crop that fixed costs are the same whether or not the benches are filled completely or only partially. Therefore, when the profitability of a crop is determined, the fixed costs connected with vacant bench space associated with a crop must also be included. This gives further importance to the need to occupy fully all bench space in a greenhouse by strategic crop rotation planning.

Some variable costs (e.g., fuel) are assigned directly to the crop as appropriate for the amount of bench space used. Some greenhouse managers keep track of variable costs on a monthly basis since certain variable costs (e.g., fuel) will vary from month to month. Other variable costs (e.g., plant materials, labor) may vary from crop to crop, therefore they should be recorded for each crop. This provides a more realistic assignment of variable costs for each crop.

Summary

Perhaps the most valuable time spent by any greenhouse manager is the time spent keeping records. Businesses that fail to keep records are likely to fail for they will make the same mistakes over and over. The main categories of records kept by the greenhouse manager include cultural records, environmental records, crop rotation plans, and cost accounting records. Each is vital to determining and maintaining the profitability of a greenhouse operation.

Credits

Longhans, Robert W. Greenhouse Management. Ithaca, NY: Halcyon Press of Ithaca, 1980.

Nelson, Paul V. Greenhouse Operation and Management. Reston, VA: Reston Publishing Co., Inc., 1985.

A greenhouse grower needs to know about the legal agreements they may be required to sign in order to grow and sell some plants. These agreements protect the company that has spent many dollars and much time developing new plant varieties. If growers want to continue to grow these new varieties, they must agree to the conditions that the companies set. It is also important to understand the law that governs these agreements.

United States Plant Variety Protection Act

Passed in 1970 by Congress, the purpose of the Plant Variety Protection Act was to encourage the development of new varieties and hybrids and to make them available to the public. It is also designed to provide protection to the people who breed, develop, or discover these new hybrids and varieties. A plant breeder or plant company may apply to the PVP (Plant Variety Protection) office to have a new plant variety protected under this law. They are issued a Plant Variety Protection certificate that will provide legal protection for the breeder for 18 years during which time the breeder or company has complete control over the new variety. For example, they can state who will grow and propagate the variety, how many generations the variety can be grown, and whether or not a royalty is to be collected. A royalty is a fee payable to the breeder or the plant company each time the new variety is propagated or the new seed is sown. If the breeder or company desires, they can release the new variety under an exclusive release (i.e., they allow only one person or company to grow the new variety). Over 2,100 of these certificates have been issued since the act was first passed.

There are two exemptions that are allowed under this act, one for farmers and one for researchers. A farmer is allowed to save seed and either plant it the next year or sell it to other farmers. For a research exemption, work is allowed in the laboratory or in a breeding program to develop new lines.

A PVP certificate provides a "patent" or protection for new plant varieties. Anyone illegally propagating and/or selling a protected variety can be prosecuted.

License Agreement

Most major companies, after developing a new variety, will usually have a plant patent (PP) issued on the variety. When the grower receives growing-on or stock plant material, the company will require the grower to sign a nonexclusive, self-propagating license agreement. See the sample licensing agreement in Figure 24.1. The terms and conditions of the agreement will vary depending on the crop and the company. Some conditions a grower might be asked to comply with follow:

1. The grower agrees to use said varieties for his or her own flowering crop for a period of one year.
2. The grower agrees to pay the company a royalty for each of the cuttings. The cost can vary, but usually it is from two to four cents per cutting.
3. The grower agrees to report mutation or bud variations or sport and give the company first right to purchase the mutation.
4. In the case of one crop, the company does not sell, but leases the plants to the grower for a year, with the grower agreeing to destroy the plants at the end of the year. Some companies will furnish labels with the variety names for the grower.

Missouri Plant Law

A copy of the Missouri Plant Law may be obtained by writing to the Missouri Department of Agriculture, Office of the State Entomologist, P.O. Box 630, Jefferson City, Mo. 65102. Essentially, the Missouri Plant Law is a booklet of the rules and regulations governing the production of nursery plants within the state of Missouri. A nursery must have their plants inspected at least once a year by the state entomologist. This official chiefly looks for insects and diseases on the plants. If the greenhouse grower plans to grow and sell nursery stock, he or she needs to be familiar with this law.

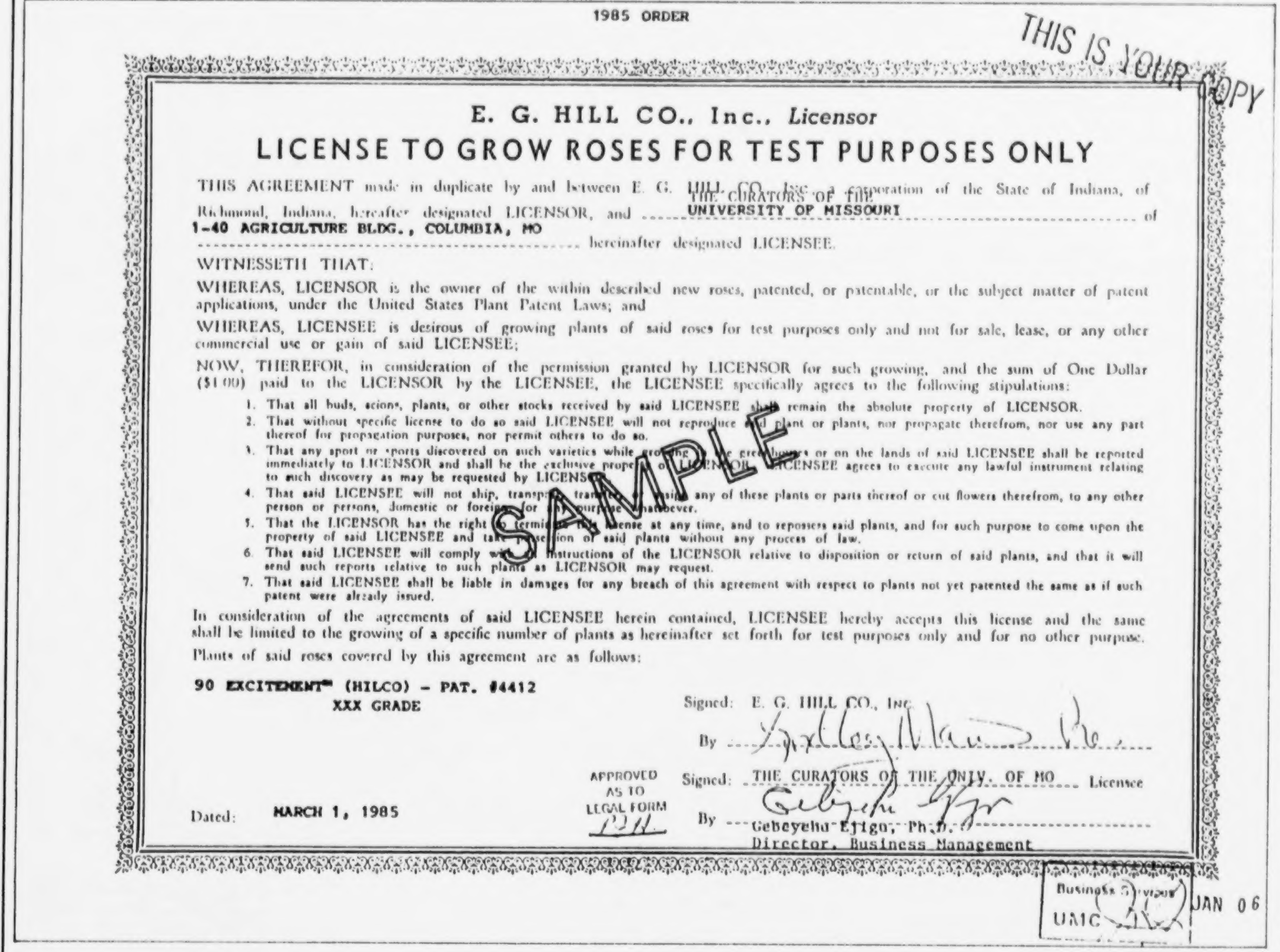
Summary

A grower must know about the various laws, regulations, and legal considerations that protect and govern the growing of plants.

Credits

Ferrin, R.K. "Some Effects of the U.S. Plant Variety Protection Act of 1970." North Carolina State University, Dept. of Economics and Business. Economics Research Report No. 46.

Missouri Plant Law. Missouri Department of Agriculture, Office of the State Entomologist, P.O. Box 630, Jefferson City, MO 65102.



1985 ORDER

THIS IS YOUR COPY

SAMPLE

E. G. HILL CO., Inc., *Licensor*

LICENSE TO GROW ROSES FOR TEST PURPOSES ONLY

THIS AGREEMENT made in duplicate by and between E. G. HILL CO., Inc., a corporation of the State of Indiana, of Richmond, Indiana, hereafter designated LICENSOR, and THE CURATORS OF THE UNIVERSITY OF MISSOURI of 1-40 AGRICULTURE BLDG., COLUMBIA, MO hereinafter designated LICENSEE.

WITNESSETH THAT:

WHEREAS, LICENSOR is the owner of the within described new roses, patented, or patentable, or the subject matter of patent applications, under the United States Plant Patent Laws; and

WHEREAS, LICENSEE is desirous of growing plants of said roses for test purposes only and not for sale, lease, or any other commercial use or gain of said LICENSEE;

NOW, THEREFOR, in consideration of the permission granted by LICENSOR for such growing, and the sum of One Dollar ($1.00) paid to the LICENSOR by the LICENSEE, the LICENSEE specifically agrees to the following stipulations:

1. That all buds, scions, plants, or other stocks received by said LICENSEE shall remain the absolute property of LICENSOR.
2. That without specific license to do so said LICENSEE will not reproduce said plant or plants, nor propagate therefrom, nor use any part thereof for propagation purposes, nor permit others to do so.
3. That any sport or sports discovered on such varieties while growing in the greenhouses or on the lands of said LICENSEE shall be reported immediately to LICENSOR and shall be the exclusive property of LICENSOR. LICENSEE agrees to execute any lawful instrument relating to such discovery as may be requested by LICENSOR.
4. That said LICENSEE will not ship, transport, transfer, or consign any of these plants or parts thereof or cut flowers therefrom, to any other person or persons, domestic or foreign, for any purpose whatsoever.
5. That the LICENSOR has the right to terminate this license at any time, and to repossess said plants, and for such purpose to come upon the property of said LICENSEE and take possession of said plants without any process of law.
6. That said LICENSEE will comply with all instructions of the LICENSOR relative to disposition or return of said plants, and that it will send such reports relative to such plants as LICENSOR may request.
7. That said LICENSEE shall be liable in damages for any breach of this agreement with respect to plants not yet patented the same as if such patent were already issued.

In consideration of the agreements of said LICENSEE herein contained, LICENSEE hereby accepts this license and the same shall be limited to the growing of a specific number of plants as hereinafter set forth for test purposes only and for no other purpose.

Plants of said roses covered by this agreement are as follows:

90 EXCITEMENT™ (HILCO) - PAT. #4412
XXX GRADE

Signed: E. G. HILL CO., Inc.

By

APPROVED
AS TO
LEGAL FORM
RH

Signed: THE CURATORS OF THE UNIV. OF MO Licensee

By Gebeyehu Ejigu, Ph.D.
Director, Business Management

Dated: MARCH 1, 1985

Business Services
UMC
JAN 06

Figure 24.1 - Licensing Agreement

Credit: University of Missouri-Columbia, Horticulture Department.

Amendment - any material, such as peat moss, processed bark, and sand, that is added to a growing medium to improve its ability to support plant growth

Acaricide - chemical pesticide directed at aracnides such as mites, ticks, or spiders

Bactericide - chemical pesticide directed at bacteria

Bulb - an underground stem that consists of layers of fleshy scales that overlap each other

Capillary action - the movement of water through a growing medium because of the adhesion of water molecules to the medium

Cation-exchange capacity - the ability of the growing medium to attract and hold nutrients

Cellular respiration - the controlled breaking down of glucose, releasing energy for plant growth, absorption, translocation and other metabolic processes

Coldframe - an unheated outdoor growing structure covered with a transparent glazing material

Complete fertilizer - a fertilizer containing nitrogen, phosphorus, and potassium

Complete flower - contains the main parts of the flower: sepals, petals, stamens, and pistils

Corm - a specialized stem that is a solid, fleshy, scale-covered enlargement

Crown - a group of closely grouped stems or plantlets just above and below the ground line

Cuttings - a method of vegetative propagation in which plant pieces are "cut" from the parent plant and rooted to form new plants

Damping-off - a fungal disease that causes seedlings to die

Day-neutral plant - a species that flowers regardless of the light/dark ratio.

Division - a method of vegetative propagation in which a plant is separated into small groups, each containing roots, stems, and leaves or the potential to develop these parts

Dolomitic limestone - limestone with a high magnesium content

Dumpage - plants remaining after the sales period; plants may be damaged and unsaleable or not damaged

Floriculture - the science and practice of flower growing and arrangement

Fungicide - chemical pesticide directed at fungi

Growth retardants - chemicals that reduce cell division and cell elongation

Growing medium - a material used for growing plants; may contain peat moss, sand, perlite, soil, or any other number of ingredients

Heading back - a pruning technique to control size and shape of plants.

Herbicide - chemical pesticide directed at weeds

Horticulture - the cultivation, processing, and sale of fruits, nuts, vegetable, ornamental plants, and flowers

Hotbed - an outdoor growing structure similar to a coldframe but heated by a source besides the sun

Imperfect flower - flower which contains male or female parts not both

Incomplete flower - is missing one or more of the main parts of a flower: sepals, petals, stamens, or pistils

Insecticide - chemical pesticide directed at insects

Lathhouse - structure shaded by lath or other material for the purpose of year-round production of plants in warm climates or during summer months

Long-day plant - a species that flowers only in a day length of critical duration

Layering - a vegetative method of propagating plants by rooting a new plant while the stem is still attached to the parent plant

Macronutrient - one of the essential elements needed in relatively large amounts for plant growth; these include nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur.

Meristem tissue - tissues that actively divide to form new growth

Micronutrient - one of the essential nutrients needed in minute quantities for plant growth; these include iron, copper, zinc, boron, molybdenum, chlorine, manganese, and cobalt

Miticide - chemical pesticide directed at mites

Molluscicide - chemical pesticide directed at slugs and snails

Nematicide - chemical pesticide directed at nematodes

Osmosis - the movement of water across a semi-permeable membrane

Perfect flower - a flower that has both male and female parts

Permanent tissues - mature cells that do not actively divide

Pesticide - a chemical used to control an undesirable organism

Phloem - part of the vascular system that transports carbohydrates from the photosynthesizing cells to the rest of the plant

Photoperiod - the light/dark ratio in a day

Photoperiodism - the influence of day length versus night length on plant growth

Photosynthesis - process by which green, living plants convert carbon dioxide and water in the presence of light into simple sugar

Phytotoxic - poisonous to plants

Pinching - removal of the terminal bud of a plant to promote branching

Propagation - plant reproduction by sexual or vegetative methods

Propagation bed - a special location within the greenhouse that is used to allow cuttings to root

Rhizome - an underground stem that produces roots on the lower surface and extends leaves and flowering shoots above the ground

Rodenticide - chemical pesticide directed at mice and rats

Rooting hormone - an auxin-type growth regulator which is used to cause cuttings to root more quickly and consistently

Scarification - the "scratching" of the seed coat so that the seed will germinate

Seed dormancy - resting stage of the seed that prevents the seed from germinating until environmental conditions are favorable

Seed germination - a process in which a seed changes into a developing seedling

Short-day plant - a species that flowers only in a daily dark period of critical duration

Stolon - A stem that grows horizontally above the soil surface

Stomata - Specialized pores in the epidermis of the leaf for the purpose of gas exchange

Stratification - exposing seeds to cold, moist conditions in order for seed germination to occur

Translocation - the movement of minerals, water, carbohydrates and other materials within the vascular system of a plant

Transpiration - the loss of water by evaporation primarily from the leaf surface through specialized pores called "stomata"

Trap crop - planting plants that attract insects for the purpose of disposing the trap crop and insects

Tuber - a short, thick, underground stem which serves primarily as a food storage area

Vascular system - the system that moves carbohydrates, water, and minerals throughout the plant; includes xylem and phloem cells

Water holding capacity - the ability of a growing medium to retain water

Wetting agent - a chemical used cause material like sphagnum peat moss to soak up water and get wet much quicker

Wick watering - method of watering in which water is moved from a reservoir to the growing medium through a fabric wick

Xylem - part of the vascular system that transports water and minerals upward from the roots to the photosynthesizing cells